

# The Canadian Entomologist

Vol. LXXXIX

Ottawa, Canada, December 1957

No. 12

## Studies of Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae)

### IV. *Neoleucopis obscura* (Hal.) (Diptera: Chamaemyiidae), an Introduced Predator in Eastern Canada<sup>1,2</sup>

By N. R. BROWN<sup>3</sup> AND R. C. CLARK<sup>4</sup>

Early in the present century the balsam woolly aphid, *Adelges piceae* (Ratz.), was introduced accidentally into North America. The history of its development and spread in the United States and Canada has been described by Balch (1952). At the present time, the adelgid occurs in eastern Canada over approximately the southern half of New Brunswick with an extension of the range in the extreme northeastern part of the Province, throughout Nova Scotia and Prince Edward Island, and in some areas of the southwestern and southeastern parts of Newfoundland.

This important pest of balsam fir, *Abies balsamea* (L.) Mill., in eastern Canada has been responsible for two types of injury to the host, a condition on the branch tips known as "gout" which often causes the slow death of the tree, or a much more rapid injury and death which results from heavy infestation of the main stem. The usual life cycle has two generations per year, the hiemosistentes (spring) generation which overwinters as a neosistens and develops early in the summer, and the aestivosistentes (summer) generation which develops during the latter part of the season.

The need for biological control of this pest became apparent soon after studies were initiated in Canada in 1931. A few native species of insect predators were found feeding on the adelgid but were apparently unable to control it adequately (Balch, 1952; Brown and Clark, 1956b). Through a cooperative arrangement between the Canadian Government and the then Imperial Institute of Entomology, a few species of predators in Europe were sent to the Dominion Parasite Laboratory, Belleville, Ontario. These were reshipped to the Maritime Provinces where they were released. A recent paper by Smith and Coppel (1956) includes records of these early introductions. Only one of these species, *Neoleucopis obscura* (Hal.), survived in Canada.

Early studies of *N. obscura* in Europe (Haliday, 1833; Hardy, 1871-72; Trägårdh, 1931; Wilson, 1938) were concerned chiefly with descriptions of the various life stages and include only brief references to life history and biology. Atwood (1933) carried out a few brief studies on initial establishment of the species following the first introductions into New Brunswick. Reeks (1943), on the basis of one season's observations, has recorded additional detail of establishment, spread, and biology.

Following the introduction and initial survival studies of this species, the present more detailed study was commenced in 1947 to determine spread and distribution, seasonal life history, habits, natural control factors and control value.

<sup>1</sup>Contribution No. 386, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Joint Project of Forest Biology Laboratory, Science Service, Department of Agriculture, Fredericton, N.B. and Department of Lands and Mines of New Brunswick, financed in part by a grant from the Provincial Department.

<sup>3</sup>Professor of Forest Entomology, Faculty of Forestry, University of New Brunswick, Fredericton, N.B.

<sup>4</sup>Research Officer, Forest Biology Laboratory, Fredericton, N.B.

TABLE I  
 Liberations of *N. obscura* in Eastern Canada

Year	Locality	No. liberated
1933	Fredericton, York Co., N.B. ....	1628
1933	Gagetown, Queens Co., N.B. ....	396
1934	Gagetown, Queens Co., N.B. ....	103
1936	Jemseg, Queens Co., N.B. ....	1125
1936	Burton, Sunbury Co., N.B. ....	436
1936	New Maryland, York Co., N.B. ....	468
1936	French Lake, Queens Co., N.B. ....	605
1936	Geary, Sunbury Co., N.B. ....	216
1936	Fredericton, York Co., N.B. ....	30
1941	Fortune Bridge, Kings Co., P.E.I. ....	491
1941	Mersey River, 18 mi. N.W. Liverpool, Queens Co., N.S. ....	533
1955	Nardinis, Newfoundland ....	2
1955	Little Barachois Brook, Newfoundland ....	19
1956	Frenchman's Cove, Newfoundland ....	55
1956	Bay of Islands, Newfoundland ....	98
1956	Cook's Brook, Newfoundland ....	189

### Liberations

Details of all releases of *N. obscura* in Canada are given in Table I and, except for those in Newfoundland, in Figure 1. All releases were of adult insects and were made in the vicinity of heavily infested trees.

### Spread and Distribution

During the summers of 1947 and 1948 a survey was carried on in New Brunswick and the Chignecto Isthmus area of Nova Scotia to determine the area of distribution of *N. obscura*. The survey was conducted by working out in all directions from Fredericton and examining heavily infested balsam fir trees for the presence of the predator. An attempt was made to locate such trees at not over 5-mile intervals along roads. In 1947 the survey in New Brunswick extended north to First Eel Lake on the west, to Deer Lake, Scotch Lake, McNamee, and Rexton on the east. This line corresponded with the northernmost limit of the host as determined during the course of the survey. The survey was extended into Nova Scotia along Northumberland Strait as far east as Alma and included Cumberland, Colchester, and the western third of Pictou Counties. Approximately the same areas were examined again in 1948. The isolated infestation of *A. piceae* at Grande Anse, N.B. was also examined. In 1950 additional *A. piceae* stem infestations were examined in the vicinity of Liverpool and Stewiacke in Nova Scotia.

The basal part of the trunk of infested trees was carefully inspected for

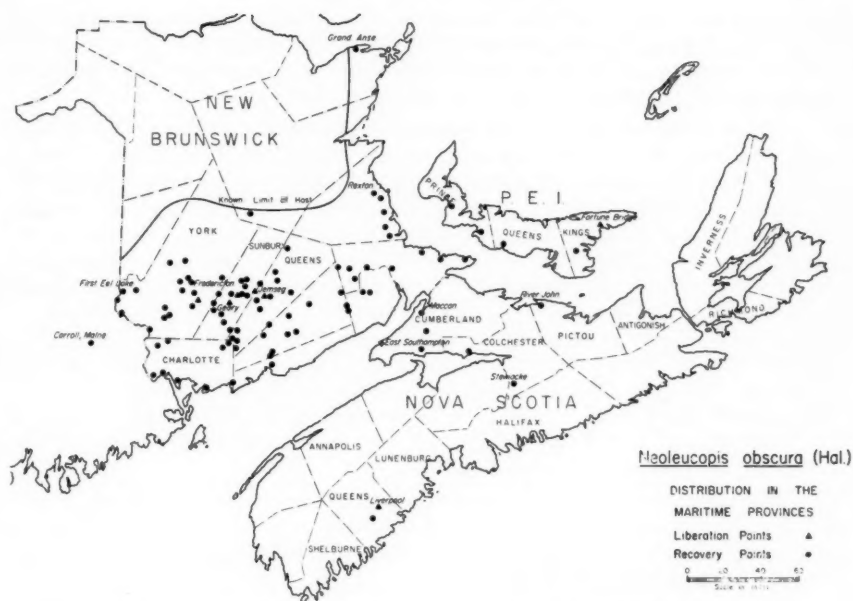


Fig. 1. Distribution of *Neoleucopis obscura* in the Maritime Provinces.

larvae, puparia or adults with the naked eye, sometimes aided by a hand lens. Loose bark scales were often removed to facilitate the search for hidden puparia and the adelgid "wool" was pulled apart. Quantitative studies of the predator were not made during these surveys. In general, two or three infested trees in a stand were examined, although this was extended to about a dozen trees if *N. obscura* did not appear to be present. The average time spent in each infested stand was about one-half hour by two observers.

In addition to these surveys, infested bark samples received by the Forest Insect Survey from many localities in Nova Scotia and Prince Edward Island, as well as a few from Newfoundland, have been examined in the laboratory.

The accompanying map (Figure 1) shows all recovery points. The results of the survey in New Brunswick showed that *N. obscura* had spread from the liberation points over roughly the complete area of distribution of the host in the Province. Throughout the central part of New Brunswick, where the heaviest stem attacks of *A. piceae* occurred, *N. obscura* was found to be numerous. It is in this area that the predator was liberated. As the limits of distribution of *A. piceae* northward were reached, fewer *N. obscura* were found and in some localities the predator was not found, even on heavily-infested trees. Along the south shore of New Brunswick "gout" is more prevalent than stem attack, and a corresponding decrease was noted in the population of *N. obscura*, which is apparently present only as a predator on stem infestations. In some areas in the interior of Charlotte County very few *N. obscura* were found in 1947, despite the fact that very heavy stem attacks of *A. piceae* were common. The reason for this predator scarcity was not apparent; not only *N. obscura*, but also native predators, e.g. *Leucopina americana* (Mall.), *Syrphus torvus* O. S. and other syrphid larvae, were scarce. In 1948 *N. obscura* was more abundant in this area.

Along the east shore of New Brunswick *N. obscura* was encountered less frequently, as along the northern border of *A. piceae* distribution. This was not the case, however, at the Grande Anse infestation in Gloucester County, where *N. obscura* larvae and puparia were numerous in 1948.

In Nova Scotia *N. obscura* was found in Colchester, Cumberland and Pictou Counties in 1947-48. Only at one of these localities (River John, Pictou County) was *N. obscura* numerous. In 1950 a heavy population of *N. obscura* was found inland from Liverpool, about 10 miles from the 1941 liberation point, and the insect was also recorded near Stewiacke, Colchester County. On *A. piceae* infestations in Inverness and Lunenburg Counties no trace of *N. obscura* was found. Examination of a large sample of infested balsam fir bark from Lakeland, Cumberland County in 1950 showed the presence of a heavy concentration of the predator. Many samples sent to Fredericton from 1947 to 1950 from other localities in Inverness, Richmond, Antigonish, Halifax, Lunenburg, Queens, Shelburne, Annapolis, and Colchester Counties have failed to reveal additional areas of distribution of *N. obscura*. To date the predator has not been recorded from Cape Breton Island or from coastal areas of the mainland of Nova Scotia other than in the Chignecto Isthmus.

Only scanty records of distribution are available for Prince Edward Island. Examination of bark samples in 1948 showed the presence of the predator at scattered locations throughout the Province although negative results were obtained from Queens and Kings Counties.

Prior to the 1955 liberations, *N. obscura* had not been recorded in Newfoundland. It was not found on bark samples from St. George district in 1949 and 1950.

*N. obscura* is known to be present in eastern Maine, where it probably spread from the New Brunswick liberations. One of us (N. R. B.) observed the predator near Carroll, Maine, about 35 miles southwest of St. Croix, N.B. in 1948. Present plans in the U.S.A. are to collect the species in eastern Maine for release in New Hampshire, Vermont, New York, and possibly Oregon, where heavy adelgid infestations occur (R. C. Brown, 1956).

Balch (1952) has stated that following liberation at Fredericton, *N. obscura* "became very numerous during the next few years, outnumbering all the native predators combined and largely replacing the native syrphids and *L. americana*." *N. obscura* has no natural means of spread other than by flight in the adult stage. The eggs are glued firmly to the bark of infested balsam fir and the young larvae are not adapted to spread by air currents. Dissemination must not only be accomplished in the adult stage, but must also be made independently of the host. The fact that the host is not evenly distributed over its present range, particularly toward the northern border of the area of distribution in New Brunswick, makes even more remarkable the presence of the predator in almost all infestations which have been examined in that Province, including the most northerly one at Grande Anse. From Grande Anse to the nearest liberation point at Jemseg is about 145 air miles. This distance was bridged by the insect in less than twelve years. As *N. obscura* has two generations per year, this would mean an average spread of over 6 miles per generation with the necessity of locating scattered infestations whenever spread occurred. Approximately the same rate of spread would be necessary for the predator to reach the region of River John in Nova Scotia by 1948.

In Nova Scotia the population near Liverpool undoubtedly originated as the progeny of the insects liberated nearby nine years previously. The population



at Stewiacke, which is about 110 miles from the Nova Scotia liberation point, could possibly have originated from either that source or as a result of continued spread from New Brunswick. The apparent lack or scarcity of *N. obscura* in general in coastal areas of Nova Scotia is at least partially explained by the small amount of *A. piceae* stem attack as mentioned previously.

Apparently *N. obscura* has spread over most of Prince Edward Island but it is not known if all this spread has been from the Fortune Bridge liberation point, which is toward the eastern end of the Province. It is possible that adults could have been carried with the prevailing summer wind from New Brunswick to the western part of the Island Province. As nothing is known of the relative population intensities throughout Prince Edward Island, this particular question can not be answered.

The question as to whether or not an introduced species such as *N. obscura* was present prior to specific introduction is often asked. In this case there would seem to be little question that the predator did not previously exist in North America. Over the main area of liberation in central New Brunswick this species has successfully competed with a native predator, *Leucopina americana*. Prior to the introduction of *N. obscura*, the native species was a common but not numerous predator of *A. piceae*. Following introduction of *N. obscura* the population of *L. americana* decreased until at present it is encountered infrequently in central New Brunswick. It was noted during the survey in New Brunswick and Nova Scotia that as the border of the area of distribution of *N. obscura* was approached, this species decreased in relative abundance and this decrease was balanced by a corresponding increase of *L. americana*. This same condition was noted in Nova Scotia in 1950. No *L. americana* was present among the material collected near the original point of liberation of *N. obscura* but at Stewiacke the two species occurred in approximately equal numbers. The type of competition involved and the reasons for these population changes of the two species are not yet fully understood.

As mentioned briefly by Balch (1952), G. E. Shewell, of the Insect Systematics and Biological Control Unit at Ottawa, has commented on this matter in correspondence. His comments, in full, are as follows:

"I think it very unlikely that *Leucopis obscura* Hal. existed on this continent as a native species prior to its introduction. My reasons are as follows:—(a) The same species, if present prior to 1933, would have existed under the same conditions as the introduced population. One would, therefore, expect that it would have been equally successful in establishing itself as a common and well-known species along the Atlantic seaboard, and that the earlier collectors would have had it in their collections. This is certainly not the case. (b) It is so markedly different from any other American species, and at the same time so clearly a member of this genus, that there is no possibility of it being present in American collections under any other name known to me. (c) It is apparently behaving just as one would expect a successful introduced species to do, i.e. increasing very rapidly over a short period, ousting the less successful native species (*americana*) etc."

In an attempt to clarify this question further, examination has been made during several seasons of infestations of other adelgids to establish whether or not *N. obscura* has other hosts than *A. piceae* in eastern Canada. Infestations of *Pineus strobi* (Htg.) on white pine (*Pinus strobus* L.), *Pineus pinifoliae* (Fitch) on red spruce (*Picea rubra* Link) and white pine, and of *Adelges abietis* (L.) and *Pineus similis* (Gill.) on red spruce have been examined. Prior to 1956, *N. obscura* was not found on any of these possible hosts. On July 19, 1956,

two adults were collected from an infestation of *P. strobi* near Fredericton and on July 22, an adult emerged from a puparium collected from the same infestation. It thus appears that *N. obscura* may occasionally act as a predator on hosts other than *A. piceae* in eastern Canada although this is not common. Other hosts of the insect are, however, known in Europe. Hardy (1871-72) records *N. obscura* as a predator on *Adelges corticalis* (Kalt.) (= *P. strobi*). Wilson (1938) states that it is the most important predator on *Pineus pini* Koch and *P. strobi* in England and that "it is found in smaller numbers feeding on larch *Chermes*". Wylie (1951) records it very abundant on infestations of *Adelges nusslini* (C.B.) at Ribeauville (France).

### Biology

Brown and Clark (1956a) in a previous paper in this series have described and illustrated all stages with particular reference to characters useful in field identification and have referred to all previous descriptions of the various stages found in the literature.

#### Life History

Information on seasonal development, based on results from eight seasons, is presented graphically in Figure 2. This figure includes the 'normal' and extreme times of occurrence of all stages.

This is a bivoltine species in Canada. Second- and third-instar larvae and puparia overwinter. Of these overwintering forms, puparia are most numerous and second-instar larvae fewest in number. Survivors continue their development the following spring; the first adults emerge from puparia about May 20 and adult activity continues until the end of June. Peak activity and oviposition are reached about June 10.

Eggs of the summer generation have been found in the field from June 7 to July 15 but probably the first are deposited earlier than June 7. First-instar larvae have been observed from June 29 to July 5. As this instar is extremely small and very difficult to observe when it is crawling about through the adelgid "wool", it is believed that these larvae are present for a longer time than observations have indicated—probably from the first of June to the middle of July. These dates would agree more closely with those given above for the egg stage. Larval development continues to the end of July. New puparia have been recorded from the end of June until the middle of August and adults emerging from them have been found from July 3 to August 12.

Eggs of the overwintering generation have been found in the field from July 22 to September 20 and the oviposition period probably begins as early as July 6. First-instar larvae of this generation occur in the field from the first of August until about September 20. Second-instar larvae have been recorded as early as August 6 and third instar on August 8. First recorded occurrence of new puparia is August 9. As stated above, some of the second- and third-instar larvae and the puparia enter the winter.

It can be seen that, although there are two generations per year, one of these generations spreads over a period of ten to eleven months while the other occurs during a one- or two-month period in mid summer.

A two-generation life cycle, similar to that described above for Canada, has been recorded by Wilson (1938) in England. Wylie (1951) says that three generations are known to occur in France. In England the larval stage hibernates while in Switzerland both larvae and puparia apparently hibernate (Delucchi, 1954) as in Canada.

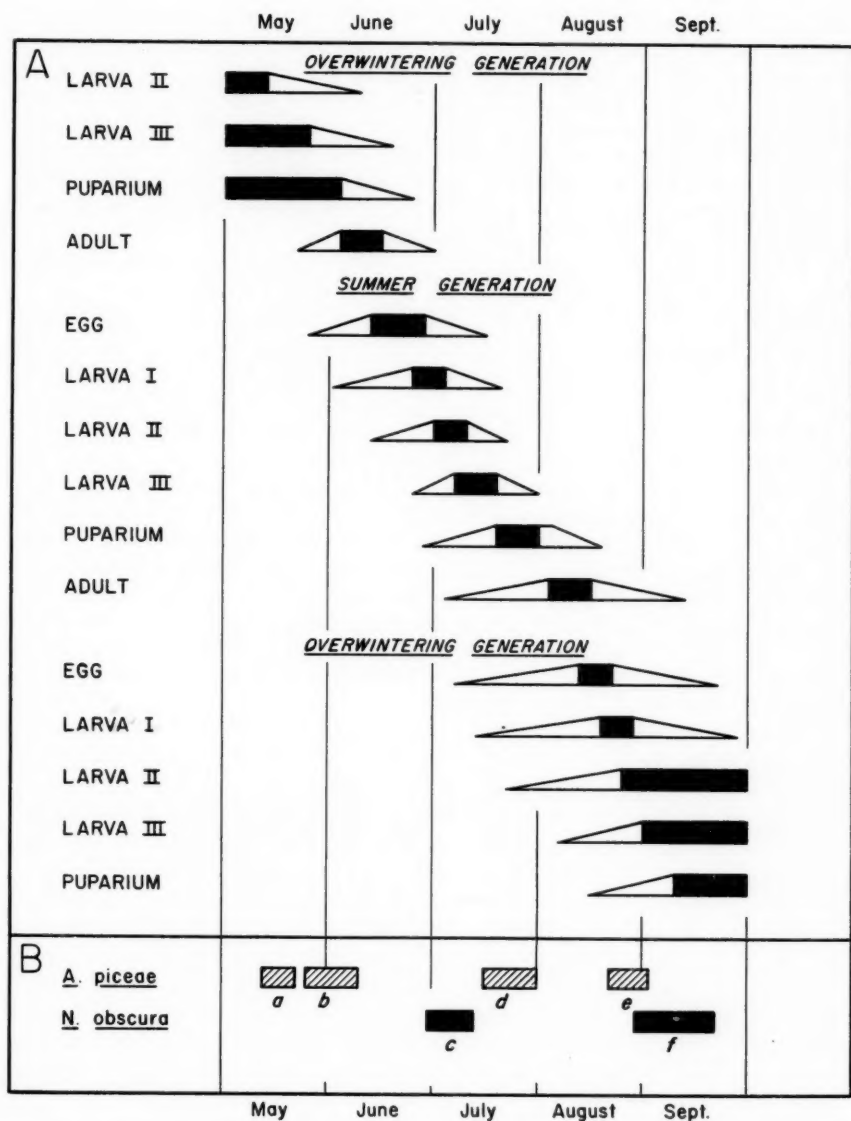


Fig. 2. A. Life cycle of *Neoleucopis obscura* (Hal.), based on records from 1947 to 1949 and 1952 to 1956. Solid areas represent normal period of occurrence; clear areas indicate extreme range.

B. Development of some stages of *A. piceae* and *N. obscura*, based on data from 1953 to 1956. a.—May 11-22. First *A. piceae* eggs laid by hiemosistentes. b.—May 24-July 8. Maximum *A. piceae* intermediate stages and adults, hiemosistentes. c.—June 30-July 12. Maximum *N. obscura* larvae, summer generation. d.—July 15-31. First *A. piceae* eggs laid by aestivosistentes. e.—August 21-September 1. Maximum *A. piceae* intermediate stages and adults, aestivosistentes. f.—August 29-September 20. Maximum *N. obscura* larvae, overwintering generation,

### Habits

Two flight periods occur during the summer, peak periods of activity being in early June and early August. At these times the adults are sometimes very numerous and may be seen in swarms flying around the trunks of heavily-infested trees. The majority of these flying insects are females. They hover over groups of adelgids, land briefly, walk around and occasionally deposit an egg on the bark, where it is firmly attached by mucilaginous secretions of the reproductive system. Eggs have never been found deposited loosely in the adelgid "wool". Nothing is known about the feeding habits of the adult flies.

From results of laboratory rearing of larvae and puparia collected in the field 1947-1949, sex ratio (male: female) of 91 adults of the overwintering generation was 1:2.25; for 94 adults of the summer generation it was 1:1.68.

Larvae occur throughout most of the year but show two peak periods of abundance. The first of these occurs during the first half of July (summer generation) and the second during late August and early September (overwintering generation). As many as 268 larvae per 1000 square inches of trunk area have been recorded (in 1953) during the latter period.

Feeding occurs mainly on adult adelgids, although some predation on earlier stages and eggs of the host has also been observed. Wilson (1938) records the larvae feeding on eggs, intermediate stages, and adults of *Pineus* spp. in England.

As has been shown (Balch, Clark, and Brown, 1956), "because of the relatively sluggish habits and large 'appetite' of the larva", *N. obscura* belongs "to the group of predators that can maintain a low 'steady density' only when their prey is strongly colonial in habit." As a result this predator is seldom found on trees with light host populations and only reaches large numbers on very heavy host populations.

From field cage and laboratory studies (Brown, Clark, and Smith, 1952) average duration of larval instars of the summer generation was found to be six days each for instars I and II and ten days for instar III.

Rearings of 66 larvae by Smith (Brown, Clark, and Smith, 1952) indicated that total prey destruction averaged 18 adelgid adults and 131 eggs per larva.

### Natural Control

#### Parasites

The only parasite recorded from *N. obscura* in Canada is *Pachyneuron altiscutum* How. (Hymenoptera: Pteromalidae). In England, Wilson (1938) has recovered three species from puparia—*Lygocerus testaceimanus* Kieff. (Hymenoptera: Proctotrupidae), *Amblynotus longitarsus* Reinh. (Hymenoptera: Cynipidae), and *Aphidencyrus aphidivorus* Mayr (Hymenoptera: Encyrtidae). Delucchi (1954) reared *Lygocerus piceae* Rat. (Hymenoptera: Proctotrupidae) and *Pachyneuron ferrièrei* Del. (Hymenoptera: Pteromalidae) from the mature larvae and puparia, respectively, of *N. obscura* in Europe.

*P. altiscutum* is apparently a little known species. It has been listed in the Review of Applied Entomology on only five occasions as being parasitic on the larch casebearer, *Coleophora laricella* Hbn., in Ontario (Graham, 1944), the juniper mealy bug, *Pseudococcus juniperi* Ehrh., in Kansas (Calkins, 1946), Comstock's mealy bug, *Pseudococcus comstocki* Kuw., in Virginia (Cox, 1940), *Clausenia purpurea* Ishii (an encyrtid parasite of *P. comstocki*) in Virginia (Clancy, 1944), and as a secondary parasite of the terrapin scale, *Eulecanium nigrofasciatum* Perg. (Simanton, 1916). We have reared it from three other

chamaemyiids: *Leucopina americana*, *Neoleucopis pinicola* Mall. and the introduced *Cremifania nigrocellulata* Cz.

Several specimens determined to date as *Pachyneuron* sp. have also been reared from a syrphid puparium (probably *Metasyrphus*).

Parasitism by *P. altiscutum* apparently occurs only on the puparium; parasite adults have not emerged from puparia formed by field-collected larvae. Reeks (1943) reported parasitism on *N. obscura* to be as high as 33 per cent, averaging about 9 per cent in puparia collected from March 9 to August 9. From puparia collected in 1947, 42 male and 23 female parasite adults emerged. Parasitism in this lot (including both host generations) was 21.3 per cent. The sex ratio of 1:0.55 varied greatly from that of 1:2.57 noted by Reeks in 1943.

Parasite adults emerged from reared puparia in every month from May to August. However, the emergence dates break down into three groups—May 22 to June 27 (mean date June 9), July 3 to July 18 (mean date July 11), and August 1 to August 16 (mean date August 8). Reeks found the mean date of parasite emergence to be June 16 and he had no emergence after July 7. Based on induced parasitism and subsequent emergence of one male adult, he stated that "It is clear that there are two generations of this parasite." The length of life history of this specimen from oviposition to emergence was 34 days. The three groups of emergence dates for 1947 as listed above suggest that there may be three generations per year. The time between the first and second mean dates is 32 days and that between the second and third mean dates is 28 days. These times are not far from the 34 days given by Reeks for the one male specimen. Referring to the life cycle diagram for *N. obscura* (Figure 2) it is seen that puparia would be available in the field for oviposition at the times necessary for each of these parasite generations. Results of rearing field-collected puparia in subsequent years have not added materially to the above data from 1947, except to extend the last parasite emergence period to September 24.

#### Predators

The only evidence of predation on *N. obscura* obtained to date is an ant (*Myrmica* sp.) observed feeding on a puparium on June 29, 1956. It is suspected that winter birds—chickadees, nuthatches, and brown creepers—feed to some extent on overwintering larvae and puparia. It is also possible that other species of *A. piceae* predators, particularly coccinellids and hemerobiids, may on occasion feed on *N. obscura* larvae although this has not been observed. Wylie (1951) observed that *N. obscura* larvae are attacked by *Chrysopa ventralis* Curtis, *Anatis ocellata* (L.) and *Aphidecta oblitterata* L. in Europe.

#### Climate

Some information is available on the effect of winter climate on overwintering puparia from studies carried on in the spring of 1948 and 1949. The 1947-48 winter was the most severe, as regards temperature, since that of 1933-34. During the 1947-48 winter the minimum recorded temperature at Fredericton was  $-31^{\circ}\text{F}$ . The minimum temperature during the 1948-49 winter was  $-21^{\circ}\text{F}$ ., which is more usual for the locality.

In the spring of 1948 and again in 1949 bark samples, measuring about 2 by 6 inches, were removed from above and below snow line from trees on which snow line had been marked during the coldest part of the previous winter. These samples were collected after all *A. piceae* had apparently begun to develop. They were examined in the laboratory and records were made, on a portion of the bark surface, of the number of developing adelgids and the number of neosistentes from the previous autumn which did not develop. Sound *N. obscura* puparia

TABLE II

Data on Mortality of *N. obscura* Puparia and *A. piceae* During Winters of 1947-48 and 1948-49 at Fredericton, N.B.

	Above snow line		Below snow line	
	1947-48	1948-49	1947-48	1948-49
No. bark samples	92	58	60	32
<i>N. obscura</i> — living	10	10	14	3
dead	106	4	26	2
% dead	91.4	28.6	65.0	40.0
<i>A. piceae</i> — developing	766	3508	1276	1365
dead	3374	536	1312	220
% dead	81.6	13.6	50.6	13.9

which had entered the winter in living condition were removed, dissected and recorded as living or dead.

Table II suggests that, although some degree of protection to the overwintering adelgids and predators was afforded by the snow, they were not given complete protection. Mortality of both insects below snow was greater during the severe winter than either above or below snow during the next winter. The predator apparently suffered greater mortality under all these conditions than the host adelgid.

Using chi-square to test the values in Table II, there is a significant difference (at the 1 per cent level) in the mortality of both host and predator above snow for the winters of 1947-48 and 1948-49. There is also a significant difference above and below snow for the winter of 1947-48. Since there were no other known mortality factors involved in the winter of 1947-48 it is assumed that the extreme minimum temperature ( $-31^{\circ}\text{F.}$ ) was responsible for the high mortality recorded for this year. Apparently about 30 per cent of the overwintering *N. obscura* puparia are killed during an average winter in the vicinity of Fredericton. The corresponding figure for the host is about 15 per cent. Winter mortality of pupae thus tends to be a constant factor in preventing the predator from keeping pace with an increasing host population and may well be important in limiting the control value of the species.

Insufficient information on numbers of overwintering larvae and overwintering mortality in this stage is available to assess the importance of this factor. Probably it is relatively unimportant as only a small number of larvae have been found in the field late in the autumn and early in the spring.

#### Control Value

##### Sampling Methods

During the development of studies on the predators of *A. piceae* the method of population estimation used for host and predators has undergone a gradual evolution. Details of these methods will be given in a future paper in this series as they were mainly devised for a study of the interactions between the host adelgid and additional predator species that have been introduced since 1951.



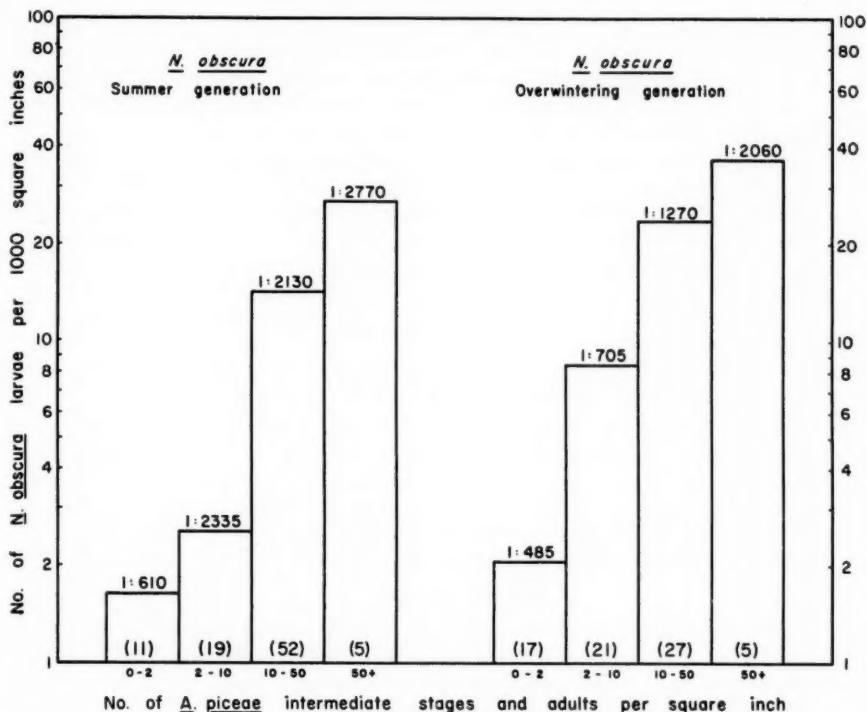


Fig. 3. Average number of *N. obscura* larvae at four host population levels, based on data from 1953 to 1956. (Numbers in brackets represent number of trees used at host population level. Ratios above blocks are Predator larvae: Host).

Most of the trees on which population counts of host and predators have been made supported heavy or medium intensity host populations, although some trees with light host populations have also been used. Host population intensities are as follows:

Light —up to 2 developing adelgids per square inch

Medium—2 to 10 developing adelgids per square inch

Heavy —over 10 developing adelgids per square inch

(For the purpose of Figure 3, heavy host populations have been further subdivided.)

### Results

From data collected in the years 1953 to 1956, it can be shown (Figure 3) that in both generations of *N. obscura*, the larval population of the predator increased with an increase in the host population. This increase, however, is not at a constant ratio and is relatively less at higher host levels.

Figure 2 shows the time of maximum occurrence of *N. obscura* larvae and of *A. piceae* intermediate stages and adults (the chief prey), and the beginning of host oviposition. From this it can be seen that the maximum numbers of *N. obscura* larvae (of both generations) occur at a later date than the time of maximum occurrence of the chief prey stages. Host oviposition begins still earlier in the season.

These results combined with others described above show why *N. obscura* has not been successful in affording effective control of host populations:

1. *N. obscura* larvae feed too late in the host developmental period to prevent the laying of large numbers of host eggs, a stage which is very seldom eaten. This is considered to be of major importance.
2. Although very little information is available, it appears that the searching ability of the larvae is insufficient to permit them to find enough food for survival on lightly infested trees, hence low host populations are not destroyed.
3. Predator populations increase at a slower rate than the host and, although the predator is abundant on heavy host populations, it does not prevent a tree-killing level from being reached. This is supported by the fact that many of the trees studied during the past few years have since died as a result of damage by *A. piceae*.
4. Overwintering *N. obscura* puparia suffer greater percentage mortality than the overwintering stage of the host.

Some of these points substantiate the observations and suppositions advanced by Balch (1952) as to the probable reasons for lack of effective control by *N. obscura*. However, despite the lack of adequate control, feeding on host intermediate stages and adults does cause some reduction in numbers, reduces the amount of oviposition and limits the number of "surplus" adelgids that spread to other trees (Balch, Clark and Brown, 1956).

#### Conclusions

In some respects the introduction of *N. obscura* into eastern Canada as a control agent of *A. piceae* has been successful. It became established rapidly at the points of release and spread widely over the range of the host. It becomes numerous at high host population levels. It does not have many enemies, although parasitism by a native pteromalid is sometimes heavy.

However, there are some weaknesses in this species. It feeds primarily on host intermediate stages and adults and infrequently on host eggs. It feeds too late in the host developmental period to prevent a large amount of host oviposition. The larvae have limited searching ability. Numbers increase at a slower rate than the host. Its establishment has apparently resulted in a decrease in population of a native predator, *L. americana*. Its presence does not prevent the host from increasing to tree-killing levels.

Within a more extensive predator complex, *N. obscura* would probably play an important part. In combination with other species which feed on host eggs or which feed at an earlier part of the host developmental period, *N. obscura* would be available for later predation. Additional predator species have recently been imported from Europe for release in the Atlantic Provinces (Smith and Coppel, 1956). Studies on their establishment, spread, and control value are now in progress and will be the subjects of future papers in this series.

#### Summary

1. *N. obscura* has been liberated in New Brunswick (1933-36), Nova Scotia (1941), Prince Edward Island (1941) and Newfoundland (1955-56).
2. Surveys in 1947 and 1948 showed that the predator had spread over almost the entire range of the host in New Brunswick and Nova Scotia.
3. Evidence indicates that *N. obscura* was not present in eastern Canada prior to these introductions.
4. *A. piceae* is the chief host of *N. obscura* in eastern Canada. *Pineus strobi* has been recorded as an occasional host.

5. *N. obscura* is a bivoltine species; the puparium is the chief overwintering stage.
6. Larvae feed mostly on host intermediate stages and adults. Eggs are very seldom eaten.
7. *Pachyneuron altiscutum* is the only parasite reared from *N. obscura* puparia in Canada. Parasitism as high as 33 per cent has been recorded.
8. *N. obscura* puparia suffer high mortality from climatic factors during hibernation; the overwintering host suffers relatively less mortality, even during severe winters.
9. Reasons for lack of adequate control by *N. obscura* are given; the most important of these is poor timing of the predator larval period.

#### Acknowledgments

The writers wish to express appreciation to Mr. G. E. Shewell and Dr. O. Peck of the Insect Systematics and Biological Control Unit, Ottawa for identification of species involved in this paper and to Mr. L. E. Williams, Forest Biology Laboratory, Fredericton for drawing the map and charts.

#### References

- Atwood, C. E. 1933. Control (of *Adelges piceae*) by predators. In Annual Report, Division of Forest Insects, Fredericton, N.B. (Unpublished.)
- Balch, R. E. 1952. Studies of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Phylloxeridae), and its effects on balsam fir, *Abies balsamea* (L.) Mill. Canada Dept. Agr. Pub. 867.
- Balch, R. E., R. C. Clark, and N. R. Brown. 1956. *Adelges piceae* (Ratz.) in Canada with reference to biological control. Proc. Tenth International Congress of Entomology, Montreal, Canada. In press.
- Brown, N. R., and R. C. Clark. 1956. Studies of predators of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae). I. Field identification of *Neoleucopis obscura* (Hal.), *Leucopina americana* (Mall.) and *Cremitania nigrocellulata* Cz. (Diptera, Chamaemyiidae). *Canadian Ent.* 88 (6): 272-279.
- Brown, N. R., and R. C. Clark. 1956. Studies of predators of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Homoptera: Adelgidae). II. An annotated list of the predators associated with the balsam woolly aphid in eastern Canada. *Can. Ent.* 88 (12): 678-683.
- Brown, N. R., R. C. Clark, and B. C. Smith. 1952. Studies on *Adelges piceae* (Ratz.) and its predators 1952. In Annual Report, Forest Biology Laboratory, Fredericton, N.B. (Unpublished.)
- Brown, R. C. 1956. Forest insect research. In 1955 Annual Report, Northeastern Forest Experiment Station, Forest Service, United States Department of Agriculture.
- Calkins, L. A. 1946. Notes on the juniper mealy bug, *Pseudococcus juniperi* Ehrhorn. *Jour. Kansas Ent. Soc.* 19 (2): 66-69.
- Clancy, D. W. 1944. Hyperparasitization of *Clausenia purpurea* Ishii, an important parasite of the Comstock mealybug. *Jour. Econ. Ent.* 37 (3): 450-451.
- Cox, J. A. 1940. Comstock's mealybug on apple and catalpa. *Jour. Econ. Ent.* 33 (3): 445-447.
- Delucchi, V. 1954. *Pullus impexus* (Muls.) (Coleoptera, Coccinellidae), a predator of *Adelges piceae* (Ratz.) (Homoptera, Adelgidae), with notes on its parasites. *Bull. Ent. Res.* 45 (2): 243-278.
- Graham, A. R. 1944. The establishment of some imported parasites of the larch casebearer, *Haplotilia laricella* Hbn., in Ontario. *Rept. Ent. Soc. Ontario* 74: 48-52.
- Haliday, A. H. 1833. Article XVII. Catalogue of Diptera occurring about Holywood in Downshire. *The Entomological Magazine* 1: 173.
- Hardy, J. 1871-72. Memoirs on Scottish Diptera. *Scottish Naturalist* 1: 256-258.
- Reeks, W. A. 1943. *Leucopis obscura*. In Annual Report, Dominion Entomological Laboratory, Fredericton, N.B. (Unpublished.)
- Simanton, F. L. 1916. The terrapin scale: an important insect enemy of peach orchards. United States Dept. Agr. Bull. 351.
- Smith, B. C., and H. C. Coppel. 1957. Releases in North America and Reviews of Bionomics in Europe of Insect Predators of the Balsam Woolly Aphid, *Adelges piceae* (Ratz.) Homoptera: Adelgidae. *Can. Ent.* 89(9): 410-420.

- Trägårdh, I. 1931. Zwei forstentomologisch wichtige Fliegen. *Zeitschr. f. angew. Entomologie* 18 (3): 672-690.
- Wilson, F. 1938. Notes on the insect enemies of chermes with particular reference to *Pineus pini* Koch and *P. strobi* Hartig. *Bull. Ent. Res.* 29: 373-389.
- Wylie, H. G. 1951. Balsam woolly aphid. In Annual Technical Report, Dominion Entomological Laboratory, Belleville, Ontario, 1950-51. (Unpublished.)

(Received August 7, 1957)

### ***Phryxe vulgaris* (Fall.) (Diptera: Tachinidae), a New Parasite of *Pieris rapae* (L.) (Lepidoptera: Pieridae) in Canada<sup>1</sup>**

By MARCEL HUDON<sup>2</sup>

Crop Insect Section, Science Service Laboratory  
St. Jean, Que.

In July, 1956, a pupa of the imported cabbageworm, *Pieris rapae* (L.), was found attached to the undersurface of a corn leaf in experimental plots at St. Jean. After the pupa had been incubated at 75°F. for six months, a dipterous parasitic larva emerged and pupated immediately; a tachinid fly emerged two weeks later. The parasite was identified by Mr. J. G. T. Chillcott, Entomology Division, Ottawa, as *Phryxe vulgaris* (Fall.). *P. vulgaris* has been reported as a parasite of *Pieris rapae*, *P. brassicae* (L.), *P. napi* (L.), and *Vanessa urticae* (L.) from many central and northern European countries (Thompson, 1946, pp. 467-469; 1947, p. 598). Aldrich and Webber (1924), Chittenden (1926), and Schaffner and Griswold (1934) reported this parasite from *P. rapae* in the United States. *P. vulgaris* has been reported from Canada only on larvae of the armyworm, *Pseudaletia unipuncta* (Haw.), in Nova Scotia and New Brunswick (Gibson, 1915, p. 14).

This is apparently the first record of this tachinid as a parasite of *P. rapae* in Canada.

#### **References**

- Aldrich, J. M., and R. T. Webber. 1924. The North American species of parasitic two-winged flies belonging to the genus *Phorocera* and allied genera. *Proc. U.S. Nat. Mus.* 63 (17).
- Chittenden, F. H. 1926. The common cabbage worm and its control. *U.S. Dept. Agr. Farmer's Bull.* 1461.
- Gibson, A. 1915. The armyworm, *Cirphus* (*Leucania*) *unipuncta* Haw. *Canada Dept. Agr., Ent. Branch Bull.* 9.
- Schaffner, J. V., and C. L. Griswold. 1934. Macrolepidoptera and their parasites reared from field collections in the north-eastern part of the United States. *U.S. Dept. Agr. Misc. Pub.* 188.
- Thompson, W. R. 1946. A catalogue of the parasites and predators of insect pests. Section 1, parasite host catalogue. Part 8, parasites of the Lepidoptera. *Imp. Agr. Bur., Parasite Serv., Belleville, Ont., Canada.* (processed)
- Thompson, W. R. 1947. A catalogue of the parasites and predators of insect pests. Section 1, parasite host catalogue. Part 9, parasites of the Lepidoptera. *Imp. Agr. Bur., Biological Control, Belleville, Ont., Canada.* (processed)

<sup>1</sup>Contribution No. 3636, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Assistant Entomologist.

(Received August 7, 1957)

## Some Notes on the Biology of *Monochamus scutellatus* (Say) (Coleoptera: Cerambycidae)<sup>1</sup>

By A. H. ROSE

Forest Insect Laboratory, Sault Ste. Marie, Ont.

### Introduction

Generally throughout eastern Canada, wood borers of the genus *Monochamus* present the greatest single threat to softwood logs that must remain in the woods throughout the summer and to standing trees killed as a result of fire or other disturbance. Although a considerable body of literature has been accumulated on the general biology and taxonomy of the economically important species (4, 5, 11, 15), on the amount of damage caused by them under particular circumstances (2, 12), and on the protection of logs from damage (1, 3, 10, 13, 14), comparatively little detail is available on their seasonal development.

During the years 1950 to 1956, an excellent opportunity to study one species, *M. scutellatus* (Say), the most generally distributed species in eastern Canada, presented itself in the Sioux Lookout district of northwestern Ontario. During this period, *M. scutellatus* became very abundant following widespread mortality of balsam fir, *Abies balsamea* (L.) Mill., as a result of depredation by the spruce budworm, *Choristoneura fumiferana* (Clem.).

All studies were conducted using balsam fir logs. Freshly cut logs, which are most attractive to ovipositing adults, were set up in rows on skids in the open in the early spring of each year of the study, and sampled semi-weekly during the field season.

### Number of Larval Instars

Nowhere in the literature is reference made to the number of larval instars through which *M. scutellatus*, or any other member of the genus, passes. Furthermore, there is a dearth of information on the number of larval instars in any species of the family Cerambycidae. Throughout this study large numbers of larvae were collected and preserved. Fully-formed larvae extracted from eggs immediately before hatching, and shed head-capsules from pupal cells, provided measurements for known first- and last-instar larvae, respectively. Cast skins of the first- and the intermediate-instar larvae were seldom found in mines, although freshly moulted larvae were occasionally found beside partially consumed exuviae. Head-capsule widths of some 2,000 larvae were measured across the ventral surface, on a line projected through the postero-lateral angle of the hypostomal sclerites. Head-capsule widths plotted as a frequency histogram indicate four overlapping distributions (Fig. 1). To separate the distributions, a method described by Harding (8) for the separation of polymodal frequency distributions, plotting the data as cumulative percentages on probability paper, was employed. This analysis revealed four separate distributions, and established the mean head-capsule width for each larval instar (Table I). Although the range in head-capsule width in the last instar is large, measurements of shed head-capsules gave a similar range and a mean width of 3.63 mm. The width of the head-capsules in successive instars does not follow Dyar's rule, nor is the increment linear (6).

### Seasonal History and Habits

In the Sioux Lookout district of Ontario, adult emergence generally takes place during June and July. About 23 months are required for development

<sup>1</sup>Contribution No. 399, Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada.

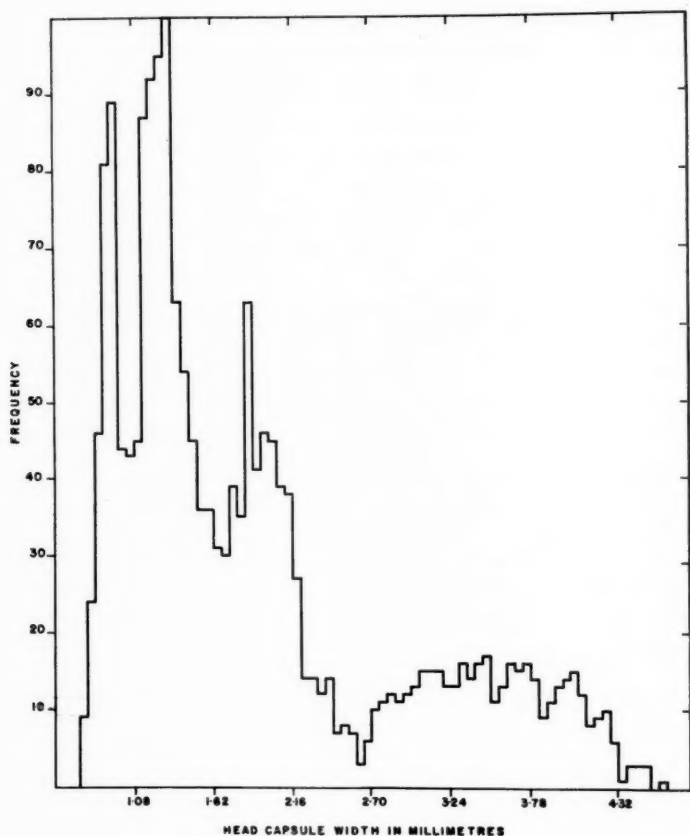


Figure 1

from the egg to the adult stage, a period similar to that reported by Belyea (2) for *M. scutellatus* in standing dead trees in the Lake Nipigon region of Ontario, some 200 miles to the east.

Adults were usually seen on the study logs for a week or ten days before mating was observed. A few oviposition slits were cut before mating, but they were invariably empty. Mating occurred on the logs during the afternoon on warm, bright days, and was followed almost immediately by oviposition in slits cut into the bark. This species is, therefore, similar in these respects to *M. notatus morgani* Hopping (9), but differs from *M. marmorator* Kby., which oviposits at night (15). Adults were seldom seen on overcast days and oviposition occurring on such days was light. Although the adults were most abundant on logs on bright days, oviposition occurred in partial shade, since many more eggs were laid on the sides and lower surface than on the upper surface of logs placed in full light (Table II). However, few eggs were laid in logs placed in full shade. Thus it seems that bright sunlight encourages mating and the search for oviposition sites, but that the high temperature and



TABLE I  
Head-capsule widths of four larval instars of *M. scutellatus*

Larval Instar	Head-capsule width in mm.	
	Mean	S.E.
1st.....	0.90	0.005
2nd.....	1.28	0.004
3rd.....	1.85	0.012
4th.....	3.60	0.023

strong radiation occurring on the fully exposed upper surfaces of logs are avoided during oviposition.

Throughout the oviposition period, approximately 70 per cent of all slits cut in the bark by ovipositing females were empty. Slits, whether utilized or not, were most abundant in the wrinkled bark surrounding branches or old branch scars and near other scars on the logs. Slits containing eggs were almost invariably cut into small cavities in the bark that appeared to be small empty resin blisters. Some slits were cut into the edge of full blisters, in which case a flow of resin resulted.

The duration of oviposition in the 6-year period varied from seven to ten weeks, but in each year 90 per cent of the eggs were laid during a period of four to six weeks. The date of first oviposition differed by approximately five weeks, from June 6 in 1952 to July 10 in 1950. Completion of 50 per cent of oviposition varied from June 29 in 1955 to July 28 in 1950; generally this point in the period was reached by mid-July. No eggs were laid after the first week of September.

The duration of the egg stage was nine to fourteen days, with a mean of twelve. After hatching, the larvae consumed the egg remnants and then tunnelled directly through the phloem to the cambium, which they reached in two or three days. Feeding in the cambial region resulted in a flat mine that barely scored the wood surface. This stadium lasted two or three weeks; thus by mid-

TABLE II  
Density of *M. scutellatus* eggs per square foot of bark surface by sectors on four sets of balsam fir logs, two sets in the open and two in shade

		Sector No.*								Ave.
		1	2	3	4	5	6	7	8	
Logs Exposed	Series 1	0.2	9.8	36.3	33.2	35.6	40.0	31.1	0.3	23.8
	Series 2	0.7	30.7	27.6	21.4	26.2	31.0	17.3	1.4	19.1
Logs Shaded	Series 1	2.0	2.5	4.7	2.7	0.8	3.0	2.3	0.7	2.3
	Series 2	1.0	3.9	3.9	2.0	1.6	1.3	2.6	0.0	2.0

\*Sectors 1 and 8 are at the top and 4 and 5 are at the bottom.

August most of the larvae were in the second instar. These larvae also fed in the cambial region, widening and extending the mines and noticeably scoring the wood surface. The second stadium also lasted two or three weeks.

During these early larval stages, especially where larval density was high, e.g. around knots and scars, separate mines often coalesced and only one larva could be found. In some instances, cannibalism was observed. It will be shown later that considerable mortality occurred under the above circumstances.

By early September the majority of the larvae were in the third instar. Although this stage marked the beginning of tunnelling in the wood, larvae still returned to the wood surface to feed, and the wood and phloem surfaces were deeply scored. The gut of these larvae was often outlined by dark material typical of phloem tissue, and the mines on the wood surface were lined with fibrous and crumbly material typical of xylem and phloem respectively. Extrusion of excess frass from the mines became noticeable at this time. Tunnels in the wood were extended and enlarged until continuous cold weather occurred.

By late September, the majority of the larvae were still in the third instar and the tunnels had been extended deeply into the wood. The remainder of the population were in the second and fourth instars; the former constructed shallow tunnels into the wood and overwintered without moulting, whereas the latter overwintered in deep tunnels, along with the third-instar larvae.

In the following spring, larval activity began with the first warm weather. Beginning early in July, the proportion of fourth-instar larvae increased rapidly, and by mid-August the population was mostly in that instar. By mid-summer, most of the larvae had reached their deepest point of penetration and begun to tunnel towards the surface. Throughout this summer further feeding occurred on the wood surface and large amounts of frass were extruded through holes in the bark. By late September most of the tunnels had been bored to within 5 mm. of the wood surface, where cells, in which the second winter was spent in the prepupal stage, were excavated and cut off from the tunnel by plugs of wood fibres.

Pupation occurred early in the third season. After about two weeks the adults emerged through circular holes cut through the wood and bark.

The duration of adult emergence varied from six to nine weeks; earliest emergence occurred as early as the end of May in 1955, a year with a very early spring, and as late as mid-June in 1951. Peak emergence generally occurred during the last three weeks of June.

The time lapse between the mid-points of adult emergence and oviposition varied from a little more than a week in 1955 to almost four weeks in 1953 and 1954.

Seasonal development of *M. scutellatus* in balsam fir logs is illustrated in Fig. 2. Although the bulk of the population required almost two years to complete development, individuals that had reached the fourth instar by the end of the first summer emerged as adults the next year. In more southerly localities a 1-year life cycle is quite common (7, 11).

#### Mortality During Development

In the above account, brief reference was made to cannibalism in early instars. During the study an attempt was made to assess population loss throughout development. There are various points during development when the population in logs may be readily measured:

- (a) Eggs may be counted in the bark to establish the initial population,

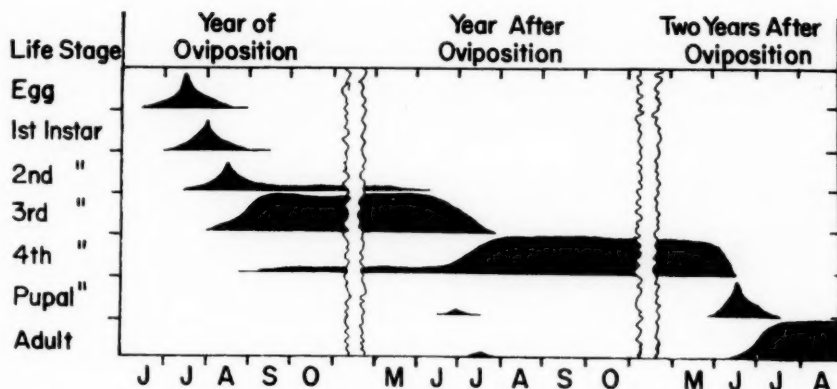


Figure 2

- (b) Second-instar larvae score the inner surface of the bark and the wood and thus provide a good estimate of the population reaching that stage,
- (c) Larval entrance holes in the wood permit an assessment of the third-instar larval population in the first summer,
- (d) In the second season, the larvae may be counted by splitting the logs,
- (e) After adult emergence, the number of exit holes gives an accurate measure of the population completing development.

Unfortunately, these counts cannot be made on the same logs, because counting usually destroys either the insects or their habitats. However, population losses between some of the points can be determined in one and the same log when markers are present that indicate the earlier population level. This is especially so at point (e) where larval entrance holes indicate the population reaching point (c). Evidence of earlier population levels is frequently destroyed by larval feeding in phloem and cambial tissues. As a result, estimates of total population loss throughout development must rest on the assumption of similar initial populations. Further justification for this assumption was obtained from 12 scattered pairs of logs that were infested in two different years of the study. In the year of infestation, all the eggs were counted in one member of the pair; two years later the adult emergence holes were counted in the other member and the difference in population was assessed as loss.

Table III records the cumulative mortality during different periods in development for logs infested in 1952, 1953, and 1954 determined from counts expressed as densities per square foot of bark surface from 90 logs. Less than 2 per cent of the insects, represented by eggs laid in these years, reached maturity. Similar high mortality is indicated in the paired logs studied (Table IV). Greatest mortality occurred between oviposition and larval establishment on the wood surface. This mortality is attributable to two factors: firstly, desiccation of the egg in those parts of the logs most exposed to the sun; and secondly, cannibalism, especially noticeable where densities were high. From larval establishment on the wood surface to larval entrance into the wood, further cannibalism was evident, and no other causes of mortality could be found. Two of the paired logs, infested in 1952 (Table IV), show a much lower mortality than the other logs, presumably because less cannibalism occurred in these logs with low initial densities. Mortality during the period from larval entrance into the wood to

TABLE III

Cumulative mortality of *M. scutellatus* in balsam fir logs infested in three different years determined from average densities per square foot of bark surface in each of four periods

Year of Infestation		1952	1953	1954
<i>Period 1</i> Oviposition to larval establishment on the wood surface	Eggs	36.5	38.8	34.6
	Larval mines on wood surface	12.6	14.1	12.4
	Per cent mortality during period 1	65.5	63.6	64.2
<i>Period 2</i> Larval establishment on wood surface to larval entrance into wood	Larval mines on wood surface	12.6	14.1	12.4
	Larval entrance holes in wood	6.6	5.7	5.6
	Cumulative per cent mortality to end of period 2	82.0	85.3	83.8
<i>Period 3</i> Larval entrance into wood to larvae in fourth instar in second summer	Larval entrance holes in wood	6.6	5.7	5.6
	Fourth-instar larvae in wood in second summer	2.3	2.8	3.8
	Cumulative per cent mortality to end of period 3	93.7	92.8	89.0
<i>Period 4</i> Larvae in fourth instar to adult emergence	Fourth-instar larvae in wood in second season	2.3	2.8	3.8
	Adult emergence holes	1.8	1.5	1.6
	Cumulative per cent mortality to end of period 4	95.1	96.1	95.4

adult emergence in the second summer was approximately 12 per cent of the total. In most instances where adult emergence had not occurred and larvae or pupae could not be found, large ragged holes through the bark over larval tunnels and into the wood at the entrance tunnels or over pupal chambers were observed and gave evidence of woodpecker activity. Belyea (2) reported 70 per cent mortality of *M. scutellatus* in standing balsam fir trees between the times of larval entrance and adult emergence, and this agrees favourably with an average mortality of 72 per cent observed in the present study. Mortalities during the

TABLE IV

Per cent mortality of *M. scutellatus* from egg to adult stage, determined from pairs of balsam fir logs infested in two years, based on density (number per square foot of bark surface) of eggs in one log and emergence holes in the other.

Year	Mean Number of Eggs	Mean Number of Emergence Holes	Per cent Mortality
1951.....	(12 logs) 48.7 $\pm$ 4.4	2.4 $\pm$ 0.32	95.0
1952.....	(10 logs) 41.7 $\pm$ 5.5 ( 2 logs) 6.7 $\pm$ 2.2	2.0 $\pm$ 0.34 2.7 $\pm$ 0.36	95.2 59.7

period from larval establishment on the wood surface to adult emergence are also comparable (78 and 87 per cent). It is probable that the initial density recorded in Belyea's study was lower because his data were collected after adult emergence when some mines had probably been destroyed by larval feeding on the wood surface, thereby giving lower apparent initial densities and thus less apparent loss.

Mortality attributable to parasites or disease, was rarely observed.

#### References

- (1) Becker, W. B., H. G. Abbott and J. H. Rich. 1956. Effect of lindane emulsion sprays on the insect invasion of white pine sawlogs and the grade yield of the resulting lumber. *J. Econ. Ent.* 49 (5): 664-666.
- (2) Belyea, R. M. 1952. Death and deterioration of balsam fir weakened by spruce budworm defoliation Pt. 1. *Can. Ent.* 84 (11): 325-335.
- (3) Blais, J. R. 1953. Borer control in balsam fir, spruce, and jack pine logs. *Can. Dept. Agr., Div. For. Biol. Bi-monthly Prog. Rept.* 9 (2): 2-3.
- (4) Craighead, F. C. 1923. North American Cerambycid larvae. *Can. Dept. Agr. Bull.* 27, New Series; 239 pp.
- (5) Gardiner, L. M. 1950. Wood borers in fire-killed pine. *Can. Dept. Agr., Div. For. Biol. Bi-monthly Prog. Rept.* 6 (3): 1-2.
- (6) Ghent, A. W. 1956. Linear increment in width of the head capsule of two species of sawflies. *Can. Ent.* 88 (1): 17-23.
- (7) Graham, S. A. 1939. Principles of forest entomology. McGraw-Hill Book Co., New York, 2nd ed.
- (8) Harding, J. P. 1949. The use of probability paper for graphical analysis of polymodal frequency distributions. *J. Mar. Biol. Assoc. United Kingdom* 28: 141-153.
- (9) Morgan, C. V. G. 1948. The biology of *Monochamus notatus morgani* (Coleoptera: Cerambycidae). *Proc. Ent. Soc. B.C.* 44: 28-30.
- (10) Morley, P. M. 1939. Time of cut as a factor influencing infestation of coniferous logs. *Can. Ent.* 71: 243-250.
- (11) Parmelee, F. T. 1941. Longhorned and flat-headed borers attacking fire-killed coniferous timber in Michigan. *J. Econ. Ent.* 34 (3): 377-380.
- (12) Richmond, H. A. and R. R. Lejeune. 1925. The deterioration of fire-killed white spruce by wood boring insects in northern Saskatchewan. *For. Chron.* 21 (3): 1-25.
- (13) Simpson, L. J. 1951. Prevention of damage by borers in softwood logs or fire-killed timber. *Can. Dept. Agr., Div. For. Biol., Proc. Pub.* 5 pp.
- (14) Swaine, J. M. 1917. Shade tree and forest insects of Manitoba. *Can. Agr. Gaz.* 4 (9): 755-763.
- (15) Swaine, J. M. and F. C. Craighead. 1924. Studies on the spruce budworm (*Cacoecia fumiferana* Clem.). *Can. Dept. Agr., Tech. Bull.* 37.

(Received August 7, 1957)

**Biology of the Diamondback Moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae), in Eastern Ontario. II. Life-History, Behaviour, and Host Relationships<sup>1</sup>**

By D. G. HARCOURT<sup>2</sup>

Crop Insect Section, Entomology Laboratory  
Ottawa, Canada

The diamondback moth, *Plutella maculipennis* (Curt.), is one of three species of Lepidoptera that annually cause serious commercial damage to cabbage and related crops in Ontario. It has long been underrated as a pest of cruciferous crops, possibly because of its small size; in eastern Ontario, it is much more numerous than the other two species and ranks second in importance to the imported cabbageworm, *Pieris rapae* (L.) (Harcourt *et al.*, 1955). Its biology in eastern Ontario was investigated from 1951 to 1956. The history, distribution, and synonymy of the insect and general descriptions of the stages were given earlier (Harcourt, 1956). This article presents the life-history, behaviour, and host relationships.

**General Methods**

Most of the field work was conducted at Merivale, Ontario, five miles south of the Central Experimental Farm, Ottawa. Although experiments were largely confined to this locality, observations were made in many other areas of eastern Ontario during the six years of the study.

The immature stages were studied in plots of cultivated crucifers grown under conditions similar to those practised commercially in the area. The adults were studied in the field and in oviposition cages outdoors; flight behaviour was studied by means of a controlled-interval light trap.

As the generations overlapped, it was not possible to determine the seasonal history of the insect by recording its stages in the field. Accordingly, the seasonal history was studied by rearing the insect in a plastic-screen cage, 6½ x 9 x 7 feet, in the field beside plots of cultivated crucifers at the Central Experimental Farm in 1953 and at Merivale in 1954 and 1955. Meteorological records showed that it did not appreciably alter the physical factors of the environment (Harcourt, 1957).

The durations of the developmental stages of the insect were recorded in conjunction with seasonal history studies.

**Life-History and Behaviour**

**Egg**

The minute eggs are laid on the leaves of the host plant. Just before hatching, the egg darkens and the young larva can be seen coiled beneath the chorion. The larva gnaws a circular opening through one end of the shell and emerges head foremost. It does not feed on the chorion after hatching.

In the field cage, the incubation period of 2,236 eggs varied from four to eight days, the average being 5.6 days (Table I).

**Larva**

The newly hatched larva crawls to the lower surface of the leaf and bores through the epidermis. During the first instar it mines the leaf tissues. Typically, the mines are shallow, the larva usually feeding in the spongy mesophyll and

<sup>1</sup>Contribution No. 3659, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Entomologist.



TABLE I

Durations in days of the developmental stages of the diamondback moth in a field cage,  
Ottawa, Ontario, 1953-1955

Stage	Range			Mean		
	1953	1954	1955	1953	1954	1955
Egg.....	4-8	4-7	4-6	5.7	6.0	5.0
Larva.....	12-30	14-24	9-30	18.6	18.8	15.2
First instar.....	3-7	4-7	3-7	4.0	5.5	4.0
Second instar.....	3-7	3-7	2-7	4.0	4.5	3.6
Third instar.....	3-8	3-5	2-6	5.0	4.0	3.4
Fourth instar.....	3-8	3-7	2-10	5.6	4.8	4.2
Pupa.....	5-11	5-9	6-15	7.8	7.8	9.8
Total.....	25-47	25-40	21-51	31.6	32.5	30.0

avoiding the comparatively tough palisade layer. The mines show up as numerous white markings on the leaves (Fig. 1). At the end of the first instar, the larva emerges from the mine, spins a few protective threads and moults beneath, selecting a sheltered site such as a depression on the leaf or near an edge that is slightly curled. At the beginning of the second instar the larva becomes a surface feeder. It does not normally again mine the leaf tissues, although larvae in all but the final instar frequently feed with head and thorax buried in the leaf. The larva commonly feeds from the lower surface, chewing irregular patches in the leaves. All the leaf tissues are consumed except the veins and the upper epidermis; this causes a "windowing" effect that is distinctive of the species (Fig. 2).

Most injury is done to the plants in the final instar. In addition to feeding on the leaves, the larvae may then attack other parts of the plant. Mature larvae often feed on the florets of cauliflower and broccoli and bore into the heads and sprouts of cabbage and brussels sprouts.

When disturbed, the larva wriggles backwards very rapidly, or drops from the leaf on a fine silken thread, frequently to the surface of a lower leaf. Often the larva merely remains suspended on the thread. When the disturbance has passed, it regains the leaf in a most interesting manner. The larva grasps the thread between its mandibles, and arching its body, brings its head close to the metathorax. Moving its head in a counter-clockwise direction it loops the thread about the bases of the metathoracic legs. It then straightens its body, grasps the thread again, and once more loops it about the leg bases. This process is repeated until the larva reaches the surface of the leaf. It then cuts the thread and crawls away, leaving a minute coil of silk on the surface of the leaf. This process lasts but a matter of seconds.

The durations of the larval instars in the field cage, on the basis of 2,022 observations, are summarized in Table I.

*Site of Feeding.*—Of 20,000 larvae observed on early and late cabbage from 1951 to 1953, 70.3 per cent fed on the lower leaf epidermis. In 1952, the percentages of larvae of each instar feeding on the lower epidermis were as follows:—



Fig. 1. Mine on a leaf of cabbage caused by first-instar larva of the diamondback moth.

Fig. 2. Injury to a cabbage plant by several larvae, showing feeding "windows".

	First	Second	Third	Fourth	Total
Number observed .....	787	1564	1690	4080	8121
Percentage on lower epidermis .....	76.7	78.0	72.4	61.8	68.6

Although there is a pronounced preference for the lower surface in all four instars, this preference is less marked in the late instars. This phenomenon may coincide with increased mandibular development. Hardy (1938) has suggested that the species, at least in its early instars, has comparatively weak mandibles. Its habit of mining the leaf in the first instar and at most times avoiding the comparatively tough upper epidermis support his thinking. Moreover, the writer observed that very little mining occurs on succulent cabbage plants in the greenhouse, where even the upper leaf epidermis is frequently consumed.

#### *Pupa*

When fully grown, the larva constructs a fine, open-network cocoon. It usually pupates on the host plant, although larvae about to pupate often wander in search of a nook or cranny affording protection. In the study cage, larvae at this period occasionally climbed the walls or ceiling. Of 11,600 pupae recorded from early and late cabbage from 1951 to 1953, 61.5 per cent were found on the basal thirds of the leaves next to the developing head.

Spinning of the cocoon is followed by one to two days of quiescence that mark the prepupal stage. The cast skin remains within the cocoon at the caudal end of the pupa. In the field cage the duration of the prepupal and pupal stages, on the basis of 2,000 observations, varied from five to 15 days, with an average of 8.5 days (Table I).

#### *Adult*

The moths are inactive during the daytime and usually rest motionless on

the lower surfaces of leaves of the host plant. When disturbed, they fly, spiralling up in narrow circles above the plant; or, alternately crawling and flying, they move swiftly from the plant in search of shelter. Wing motion is almost imperceptible, causing the latter movement to appear as a series of short "jumps". On a windless day their flight appears hesitant, the moths seldom rising more than five feet above the ground and typically travelling no more than 10 to 12 feet horizontally. They are weak flyers and are readily carried by the wind. They become active just before dusk, and move to the blossoms of nearby cruciferous weeds to feed.

Oviposition begins shortly after dusk and reaches its peak about two hours later, few eggs being laid after midnight. The female crawls slowly over the leaf surface and, after probing momentarily with the tip of her ovipositor, deposits a single egg. She may or may not return to append additional eggs. The eggs are usually laid on the leaves, but occasionally, if the plants are small, on the stems and petioles. Typically, they are laid in depressions of the leaf along the midrib and larger veins, or on the concave surfaces of the smaller veins. Other favoured sites are yellow patches on the leaf and in feeding "windows" of the larvae.

*Longevity, and Fecundity of Females.*—In experiments on fecundity and longevity in 1953 and 1954, moths were reared from cocoons collected at random in the field at approximately weekly intervals and placed in  $\frac{3}{8}$  inch gelatin capsules. On the day of emergence, adults were liberated in pairs in screened oviposition cages with sliding glass fronts, 1 x 1 x 1 foot, on the shelves of the field cage. A small, potted plant of Penn State Ballhead cabbage was placed in each cage. The moths were fed on a solution of sugar (glucose, 12.5%; fructose, 12.5%; water, 75%), contained in 27 x 8 mm. watch glasses. The sugar solution was more suitable than one of honey because it was not so sticky on drying and trapped fewer moths during feeding. Preliminary studies showed that females fed on the sugar solution were equally fecund and long-lived as those fed on the honey. Starved females lived for a shorter period and laid fewer eggs than those fed on either solution.

The eggs were counted daily. Because the moths readily escaped it was necessary to flush them from hiding and drive them to the back of the cage before removing the plants for examination. Any that did escape were not recaptured as even a slight degree of handling injured them sufficiently to curtail egg production. Table II shows that the female lived from 7 to 47 days, averaging 16.2; the male lived from 3 to 58 days, averaging 12.1. The number of eggs laid per female ranged from 18 to 356, the mean being 159. Ninety-five per cent of the females began to oviposit on the day of emergence. Egg-laying lasted about 10 days, the peak occurring on the first night of oviposition except when temperatures at sunset were below 66° F. The coefficient of correlation between sunset temperatures and the percentage of females having their peak oviposition on the first night was 0.94. Despite the small size of the plants used in the experiments, only 21.1 per cent of 16,085 eggs were laid on the stems and petioles.

*Sex Ratio and Mating.*—Among 2,480 reared individuals the ratio of males to females was 52.9 : 47.1, indicating a normal sex ratio.

Mating begins at dusk on the day of emergence. It takes place while the moths are resting on the plant. When copulating, the pair face in opposite directions and hang downward, the female above and the male below. Normally there is no motion save beating of the antennae. If the pair are disturbed, the

TABLE II  
Longevity, oviposition periods, and numbers of eggs laid  
by the diamondback moth in a field cage, Ottawa, Ontario, 1953-1954

Date study begun	Males		Females			
	Number observed	Average life-span, days	Number observed	Average life-span, days	Average number of eggs laid	Average oviposition period days
1953						
July 23	12	10.6	12	13.2	194.7	8.0
July 30	11	11.4	11	13.0	122.9	7.4
August 8	12	10.2	12	16.6	95.4	6.4
August 14	12	14.6	12	18.4	130.2	9.8
August 20	12	10.0	11	12.0	179.4	10.0
August 27	12	15.6	12	15.2	194.8	9.0
1954						
July 12	12	14.0	11	20.2	210.2	14.7
August 7	11	10.5	10	18.5	123.9	12.6
August 18	11	12.2	10	19.1	182.7	15.1
	105	12.1	101	16.2	159.4	10.3

female drags the male to a more sheltered location. Mating lasts about one hour, although individuals have been observed in copula upwards of two hours. There is no apparent courtship.

Females mated only once. When fertilized, they did not attempt to copulate again, and had little attraction for the males. However, mated males were attracted by virgin females and mated as many as three times. No sterile males were observed.

*Oviposition in the Field.*—From 1951 to 1954, 15,000 eggs were recorded from cabbage in the field. Of these, 63.4 per cent were on the upper leaf surface. The number of eggs on individual plants varied with size of the plants and degree of infestation but ranged from 0 to 164. Less than one per cent of the eggs were laid on the stems and petioles.

These findings on where the eggs are laid do not agree with those of most other workers. For example, Marsh (1917), Muggeridge (1930), Robertson (1939), Kanervo (1936), and Miles (1924) state that the eggs are laid principally on the lower leaf surface. Only the results of Gunn (1917) support those of the writer. Although the eggs may perhaps be laid principally on the undersides of the leaves in other regions, many of the published reports may have been based on insectary rearing or on too few observations in the field. The writer noted that when closely confined the moth does not oviposit normally; it lays more eggs on the stems of the plant than in the field and often lays large numbers on the sides or bottoms of the containers.

Of 2,298 eggs recorded from cabbage in the field in 1952, the grouping was as follows:—

Number of eggs in group	Frequency of occurrence	Percentage of total eggs
1	1261	54.9
2-3	327	32.0
4-8	54	12.1
more than 8	2	1.0

As many as 14 eggs were laid in a single group.

*Flight.*—In 1951 and 1952, moths were trapped in a New Jersey mosquito light trap (Mulhern, 1942). From 1953 to 1956, moths were trapped in a controlled-interval light trap developed at Ottawa (Harcourt, 1954). Each year the trap was placed about 40 feet from the southern edge of plots of cabbage. South of the trap was a large weedy pasture; to the west was a field of vegetable crops, principally Cruciferae; to the east was a vegetable garden and, beyond, chiefly pasture. The trap was operated each year from May 1 to October 31. The night was assumed to begin half an hour after sunset and to end half an hour before sunrise, so that the operational period of the trap varied from 8 to 10 hours.

The moth was in flight for about 136 days each year, on the average from May 24 to October 6. The flight period, the number captured, and the percentage that were males for each of the six years were as follows:—

	Flight period	Number captured	Percentage males
1951	June 3—October 5	238	58.0
1952	May 30—September 27	637	61.1
1953	May 9—September 30	2,333	53.6
1954	May 23—October 13	677	56.6
1955	May 23—October 3	6,309	-
1956	May 28—October 19	590	55.8
		10,784	55.6

Although the number taken in a single night varied from one to 1,183, the data did not indicate a definite separation into broods. The heaviest period of flight was from late July to early September.

Table III shows that almost a quarter of the moths were captured during the hour beginning 90 minutes after sunset and that about two-fifths were taken in that and the next hour. Thereafter the number decreased in an almost linear fashion, only 3.2 per cent of the captures being made in the final hour. These results agree with those of Williams (1939).

Although both sexes were captured in progressively decreasing numbers after the second hour, more females than males were captured during the first two hours of the night, after which the ratio was reversed (Table III). According to Turner (1918), the sexes are about equally attracted to light. The writer's data, however, indicate that response of the male to light is stronger than that of the female, although not to the same degree as indicated by Williams (1939). Of 261 females captured in 1956, 76 per cent were gravid.

The following flight behaviour was observed in the laboratory: Shortly before midnight on August 8, 1953, six newly emerged adults, three members of each sex, were liberated near a study lamp containing a 100-watt incandescent bulb. Both sexes immediately rose to the light and flew in wide circles about the bulb, landing five to six inches from it. The males soon dropped to a piece of white foolscap placed 14 inches below the light, and flew in a series of backward "jumps" of one to two inches across the page. After an average of nine "jumps", they again rose to the light and repeated the cycle. The fe-

TABLE III  
Numbers of the diamondback moth caught in a light trap in various hours of the night,  
Ottawa, Ontario, 1953-1956

Year	Hour of night*									Total
	1	2	3	4	5	6	7	8	9	
1953.....	577	521	337	281	219	163	132	81	22	2333
1954.....	198	158	98	54	64	39	32	17	17	677
1955.....	900	1527	1037	733	744	512	334	259	263	6309
1956.....	110	113	115	79	71	31	28	25	18	590
	1785	2319	1587	1147	1098	745	526	382	320	9909
Percentage.....	18.0	23.4	16.0	11.6	11.1	7.5	5.3	3.9	3.2	100.0
Ratio $\left(\frac{\text{males}}{\text{females}}\right)$ .....	0.88	0.95	1.46	1.44	1.64	1.45	1.87	1.56	1.31	

\*Beginning half an hour after sunset.

males were much less active and rested for long periods between flights. The moths did not attempt to mate in the presence of the light. Similar flight behaviour in the laboratory was later observed on several occasions.

#### Seasonal History

Although the first generation develops largely on cruciferous weeds, subsequent generations breed on cultivated Cruciferae. The seasonal history was studied from 1953 to 1955. Because the technique used was the same in all three years, it is described only for 1955. The first appearance of the insect at Merivale was detected by the capture of a female in the light trap on the night of May 23. Daily inspections of wild Cruciferae in the study area throughout May showed that the first eggs were laid on yellow rocket, *Barbarea vulgaris* R. Br., on the same night. Net sweeps of yellow rocket shortly after sunset on May 25 yielded several gravid females. These were immediately liberated in the study cage. Six small, potted plants of Golden Acre cabbage were placed on the sod floor of the cage. A total of 43 eggs had been laid by the following morning. These hatched on May 31; the larvae pupated on June 16. Issuing adults were permitted to fly freely in the cage and to oviposit on fresh plants; after the peak of egg-laying had occurred they were captured or killed to prevent extended oviposition. This process was repeated throughout the season until development of the insect ceased. In all, 544 individuals were reared to maturity.

The study showed that four to six generations of the moth occur annually at Ottawa (Table IV). There were five complete generations and a partial sixth in 1953 and 1955, one generation less in 1954. Few eggs were laid by adults that emerged in October. Except in 1953, when temperatures were above normal for the month, these did not hatch. The period from egg to adult varied from 21 to 51 days, with an average of 31.6 days.

Although the moth breeds continuously during the winter months in southern regions of North America, in northern regions it hibernates in the adult stage, seeking shelter amongst crop debris left in the field. From a survey of literature it appears that the dividing line approximates the 36th parallel of latitude.



TABLE IV  
Median dates of beginnings of various stages\* of the diamondback moth when reared in an outdoor cage, Ottawa, Ontario, 1953-1955

Generation	Egg	Larval instar				Pupa	Adult
		First	Second	Third	Fourth		
1953							
First.....	May 9	May 15	May 19	May 23	May 29	June 4	June 11
Second.....	June 11	June 16	June 19	June 22	June 25	June 28	July 6
Third.....	July 6	July 11	July 14	July 17	July 20	July 25	August 2
Fourth.....	August 6	August 10	August 13	August 16	August 21	August 27	September 1
Fifth.....	September 2	September 8	September 15	September 22	September 30	October 8	October 19
Sixth.....	October 19	October 27					
1954							
First.....	June 4	June 8	June 13	June 17	June 21	June 24	July 3
Second.....	July 4	July 11	July 17	July 21	July 25	August 1	August 9
Third.....	August 9	August 15	August 19	August 22	August 25	August 29	September 3
Fourth.....	September 3	September 10	September 17	September 24	September 29	October 4	October 13
Fifth.....	October 13						
1955							
First.....	May 25	May 31	June 4	June 8	June 12	June 16	June 26
Second.....	June 28	July 2	July 5	July 7	July 10	July 13	July 20
Third.....	July 20	July 25	July 28	July 31	August 2	August 4	August 10
Fourth.....	August 10	August 14	August 17	August 19	August 21	August 23	September 3
Fifth.....	September 3	September 9	September 16	September 23	September 29	October 9	October 24
Sixth.....	October 24						

\*Point at which 50 per cent of a given stage had transformed to the next stage.

Extensive studies from 1952 to 1956 showed almost conclusively that the moth does not overwinter at Ottawa, latitude  $45^{\circ} 34'$ . Eggs and larvae in the field survived only until mid December. Pupae collected after the end of November and brought into the laboratory failed to yield adults. Adults in hibernation cages remained alive only until mid January.

It is thus apparent that annual infestations of the insect in eastern Ontario may be attributed to moths that overwinter in more southerly regions, and migrate north in the spring as the weather moderates. In England, the moth has long been considered to be a migrant, and according to Hardy (1938) the chief source of infestations on the east coast of that country is migrating swarms from continental Europe. List (1937) has observed a migrating flight of the insect in North America.

#### Host Relationships

In addition to cabbage, cauliflower, turnip, radish, broccoli, brussels sprouts, and other cultivated crucifers the insect attacks a number of weeds belonging to the same family. On these it develops in the absence of the preferred cultivated hosts. The importance of the wild host plants is greatest in the early spring when there are no cultivated crucifers in the ground. However, the writer found the species in small numbers on wild Cruciferae throughout its active season. In eastern Ontario, it is commonly found on the following weeds: *Thlaspi arvense* L., *Lepidium densiflorum* Schrad., *Capsella bursa-pastoris* (L.) Medic., *Brassica kaber* (D.C.) L.C. Wheeler var. *pinnatifida* (Stokes) L.C. Wheeler, *Brassica hirta* Moench, *Erysimum cheiranthoides* L., and *Barbarea vulgaris* R. Br. The latter, which blooms in the early spring, appears to be a favoured host. The heavy infestations of the insect in eastern Ontario during the past few years may be associated with the rapid spread of this weed, which is reported to have spread more than any other weed in Ontario in recent years (Frankton, 1955).

In 1954, in an experiment on attractiveness of hosts, seven commonly cultivated crucifers were grown in adjacent seedbeds and were transplanted at the same stage of development. They were set out during early July in a Latin Square, each of the 49 plots consisting of three adjacent 5-plant rows. One plant per plot, from the centre row only, was examined for larvae during each of five inspections. The numbers of larvae found on the several kinds of crucifers were as follows:—

							Difference for significance at 1% level
Kohlrabi	Kale	Brussels Sprouts	Broccoli	Cauliflower	Cabbage	Collards	
607	727	911	1088	1166	1220	1363	462

There were no significant differences between the numbers of larvae found on the last five crucifers. Kale supported lower populations than most members of this group, possibly because its curled and crumpled leaves did not afford attractive oviposition sites. Kohlrabi was equally unattractive to the insect, probably because of its relatively sparse foliage. These results support those of Harrison and Brubaker (1943).

#### Summary

A six-year study of the diamondback moth, *Plutella maculipennis* (Curt.), near Ottawa, Ontario, showed that during the daytime the adults rest on the host plants. Activity begins just before dusk, reaching a peak well before midnight. Mating occurs on the day of emergence. Outdoors, caged females laid 18 to 356 eggs, the average being 159. Egg-laying lasted about 10 days, the

peak occurring on the first night of oviposition except when the temperature at sunset was below 66° F.

In the field, the number of eggs laid on individual cabbage plants ranged from 0 to 164. About 50 per cent more eggs were laid on the upper surfaces of the leaves than on the lower; few were laid on the stems and leaf petioles. Almost as many eggs were laid in small groups as were laid singly. In a field cage the incubation period for 2,236 eggs averaged 5.6 days.

The larvae feed from the lower leaf surface, consuming all the tissues except the veins and the upper epidermis. First-instar larvae, however, mine the leaf, feeding in the spongy mesophyll layer. For 2,022 larvae, the average durations of the instars, in days, were as follows: first, 4.5; second, 4.0; third, 4.1; and fourth, 4.9.

Pupation normally occurs on the host plant. The prepupal period was 1 to 2 days; for 2,000 individuals the duration of the pupal stage was 5 to 15 days, the average being 8.5. The sex ratio was normal. The life-span of 101 female moths averaged 16.2 days; that of 105 males, 12.1 days.

There were four to six generations per year. The first generation developed mainly on cruciferous weeds, subsequent generations on cultivated Cruciferae. The insect apparently does not hibernate at Ottawa.

Studies with a controlled-interval light trap showed that the moth was in flight for an average of 136 days each year, that the heaviest period of flight was from late July to early September, and that the peak of flight in the night occurred during the hour beginning 90 minutes after sunset.

*Barbarea vulgaris* R. Br. is a preferred weed host. However, in an experiment on attractiveness of hosts, the insect showed little preference between seven commonly cultivated crucifers.

#### References

- Frankton, C. 1955. Weeds of Canada. Canada Dept. Agr. Pub. 948.
- Gunn, D. 1917. The small cabbage moth (*Plutella maculipennis* Curtis). South Africa Dept. Agr. Bull. 8.
- Harcourt, D. G. 1954. The biology and ecology of the diamondback moth, *Plutella maculipennis* (Curt.), in eastern Ontario. Ph.D. thesis. Cornell University.
- Harcourt, D. G., R. H. Backs, and L. M. Cass. 1955. Abundance and relative importance of caterpillars attacking cabbage in eastern Ontario. *Canadian Ent.* 87: 400-406.
- Harcourt, D. G. 1956. Biology of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae), in eastern Ontario. I. Distribution, economic history, synonymy, and general descriptions. 37th Rept. Quebec Soc. Prot. Plants, 1955, pp.155-160.
- Harcourt, D. G. 1957. An outdoor study cage for phytophagous insects. *Ann. Rept. Ent. Soc. Ontario* 87: 11-14.
- Hardy, J. E. 1938. *Plutella maculipennis*, Curt., its natural and biological control in England. *Bull. Ent. Res.* 29: 343-372.
- Harrison, P. K., and R. W. Brubaker. 1943. The relative abundance of cabbage caterpillars on cole crops grown under similar conditions. *J. Econ. Ent.* 36: 589-592.
- Kanervo, V. 1936. The diamondback moth (*Plutella maculipennis* Curt.) as a pest of cruciferous plants in Finland [in Finnish]. *Valt. Mattalousk. Julk. No.* 86. Helsingfors, Finland.
- List, G. M. 1937. Possible migration of diamondback moth. *J. Econ. Ent.* 30: 676.
- Marsh, O. H. 1917. The life history of *Plutella maculipennis*, the diamondback moth. *J. Agr. Res.* 10: 1-10.
- Miles, H. W. 1924. The diamondback moth, *Plutella maculipennis*. *Ann. Rept. Kirton Agr. Inst.*, 1923, pp. 45-48.
- Muggeridge, J. 1930. The diamondback moth. Its occurrence and control in New Zealand. *New Zealand J. Agr.* 41: 253-264.
- Mulhern, T. D. 1942. New Jersey mechanical trap for mosquito surveys. *New Jersey Expt. Sta. Circ.* 421.
- Robertson, P. L. 1939. Diamondback moth investigations in New Zealand. *New Zealand J. Sci. and Tech.* 20(A): 330-340.

- Turner, W. B. 1918. Female Lepidoptera at light traps. J. Agr. Res. 14: 135-149.  
Williams, C. B. 1939. An analysis of four years captures of insects in a light trap. Part I. General survey; sex proportion; phenology; and time of flight. Trans. Roy. Ent. Soc. London 89: 79-132.

(Received September 12, 1957)

**Studies of the Byron Bog in Southwestern Ontario. III. *Exyra rolandiana* Grt. (Lepidoptera: Phalaenidae) Reared from the Pitcher-plant, *Sarracenia purpurea* L.<sup>1</sup>**

By W. W. JUDD<sup>2</sup>

In the description of the Byron Bog (Judd, 1957) it was pointed out that the Pitcher-plant, *Sarracenia purpurea* L., is a plant commonly associated with leather-leaf, *Chamaedaphne calyculata*, in the "*Chamaedaphnetum calyculatae*" association in the bog. The period of blooming of this plant in 1956 was from June 13 to June 22. During this period, and subsequently, collections were made of larvae of the moth *Exyra rolandiana* Grt. from the flowers and leaves. The moths were kindly identified by Mr. D. F. Hardwick, Systematic Entomology, Department of Agriculture, Ottawa.

On June 18 a larva was found in a flower of *S. purpurea*. It had chewed the petals and stamens of the flower. The flower, with the larva in it, was placed in a jar and on June 22 the larva spun a cocoon. On July 4 a moth emerged. It is deposited in the collection of the Department of Zoology, University of Western Ontario. Lloyd (1942) points out that after hibernation the larvae of *E. rolandiana* are voracious and attack not only the leaves but the flowers, which they devour.

On June 23 a larva was found in a leaf of 1956. It had spun a thin web of silk across the mouth of the leaf and had chewed away the inner tissues of the leaf, leaving the wall of the chamber of the leaf thin and transparent. A mass of frass and chewed leaf tissue had accumulated in the bottom of the leaf. The larva failed to survive.

On June 29 a leaf of 1955 contained one larva. The whole top of the leaf was collapsed, having had its inner tissues chewed out, and a silk web was spun across the chamber of the leaf about two-thirds of the distance down the leaf and was covered with chewed leaf tissue and frass. The larva was collected in its prepupal condition. On July 14 it produced an adult which is deposited in the Canadian National Collection.

On July 5 ten leaves, a few feet from one another, were found in a condition characteristic of leaves attacked by *E. rolandiana*. One leaf had a silk web across its mouth and contained chewed leaf tissue and frass. The other leaves had been chewed so that their tops were collapsed, and frass and chewed leaf tissues had accumulated in their chambers. No larvae or pupae were present in them. The destruction of these leaves was probably the work of larvae from one cluster of eggs, for Lloyd (1942) points out that a female moth lays a group of eggs in a pitcher of a single plant of *S. purpurea* and that the larvae spread out to closely placed pitchers until eventually only a single larva occupies each pitcher.

**References**

- Judd, W. W. 1957. Studies of the Byron Bog in southwestern Ontario. I. Description of the bog. *Can. Entomol.*, 89: 235-238.  
Lloyd, F. E. 1942. The carnivorous plants. Chronica Botanica Co., Waltham, Mass.

<sup>1</sup>Contribution from the Department of Zoology, University of Western Ontario; a project supported by funds from the government of Ontario granted through the Ontario Research Foundation.

<sup>2</sup>Associate Professor Zoology; the collections were made and the data assembled while the writer held a Summer Research Associateship of the National Research Council in 1956.

(Received September 12, 1957)

## The Chromosomes of *Rhopalurus* (Scorpiones-Buthidae)

By S. DE TOLEDO PIZA, JR.

Escola Superior de Agricultura "Luiz de Queiroz"  
Universidade de S. Paulo, Brasil

### Introduction

In a series of papers it has been shown that *Tityus* chromosomes are provided with one centromere at each end (2, 4, 5 and 6). Proofs of such a view were found in the behaviour of the chromosomes in the course of spermatogenesis in the widely distributed Brazilian species *T. babilensis* (Perty). Indeed, the long rod-shaped bivalents of this interesting species orient themselves in such a way that, while their bodies lie flat in the equatorial plane, the partners' corresponding ends are turned towards opposite poles. Metaphase side views show that the paired chromosomes are separated throughout their length. Being entirely unconnected by chiasmata, the chromosomes move toward the poles in perfect parallel, with the ends forward until late anaphase, when they bend strongly. Fragments bearing a single terminal centromere perform anaphase movement parallel to the spindle axis, as do the orthodox acrocentric rod-shaped chromosomes (11).

Observations like those of Rhoades and Kerr (14) on irradiated chromosomes, aimed at proving the polycentric nature of *Tityus* chromosomes, were discussed elsewhere and discarded as poor demonstrations (12). Brieger and Graner (1) thought they had found chiasmata in *T. babilensis* chromosomes. Their paper, however, was thoroughly analysed and their conclusions were rejected as completely erroneous (7). Sharp (15), in the first publication of his book, presented a photograph showing diplotene in *Tityus* (courtesy of Brieger and Graner), but, a little later, in the second publication of the same edition, after further consideration of the matter, replaced it with a drawing representing true chiasmata in the amphibian *Desmognathus* (16).

One of the most interesting peculiarities of *Tityus* meiosis is the high frequency of all sorts of translocation figures due to spontaneous breakage of the chromosomes. This undoubtedly is the result of the chromosomes having two terminally localized centromeres, in consequence of which any intercalary twist or wrong orientation may cause the chromosomes to break into two equal or unequal pieces (see figs. 13 and 16 in 3; figs. 18, 19, and 20 in 6; and fig. 52 in 17).

Meiosis in the male of *T. mattogrossensis* (8), *T. trivittatus* (10), and *T. metuendus* (13) closely follows that of *T. babilensis*. *Isometrus maculatus*, in the same family (Buthidae), also parallels *Tityus* in the structure and behaviour of its chromosomes (9).

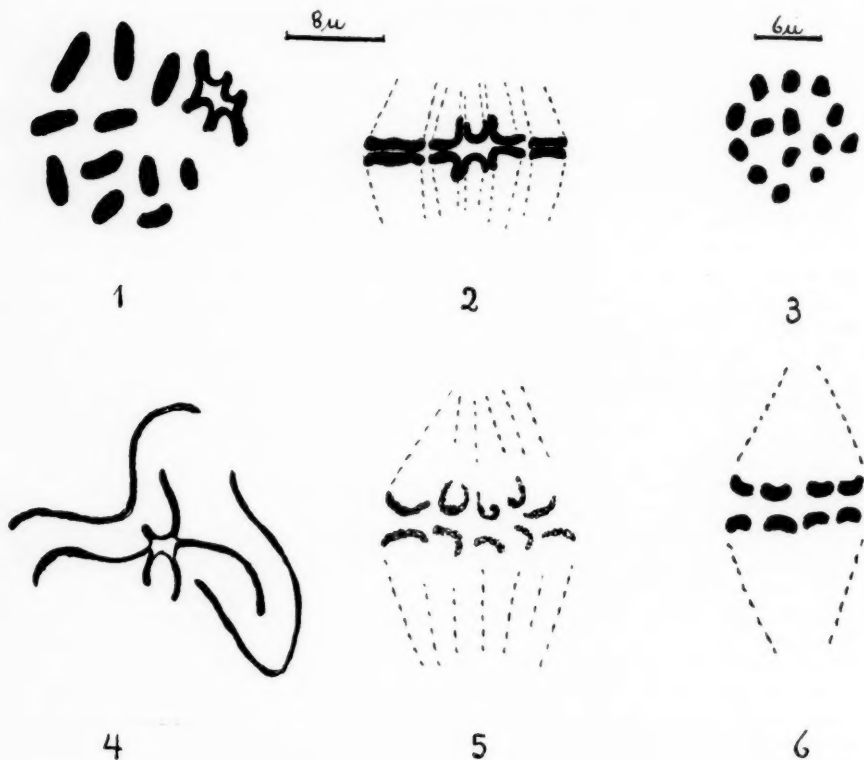
### Material and Method

A single male of *Rhopalurus rochai* Borelli, a north-eastern Brazilian species, collected by Dr. Aristoteles d'Araujo e Silva in the State of Alagoas was studied. Part of the testis was squashed in acetic orcein and part fixed in Allen-Bauer's modification of Bouin, cut at 12-14 micra, and stained with Heidenhain's haematoxylin.

### Observations

Spermatogonia possess 28 short chromosomes of different sizes.

Primary spermatocytes show 11 thick rod-shaped bivalents, the longer ones being about three times as long as the shorter, and a beautiful group formed by six elements, four longer, of approximately the same size, and two much shorter ones (Fig. 1). Metaphase orientation and anaphase movement are parallel to the



#### Meiosis in the male of *Rhopalurus rochai*

Fig. 1—Primary spermatocyte metaphase in polar view, showing 11 bivalents and the hexavalent complex; Fig. 2—Primary spermatocyte metaphase in side view, showing in the middle the hexavalent group; Fig. 3—Secondary spermatocyte metaphase in polar view; Fig. 4—Primary spermatocyte late pachytene, showing two normal bivalents and the hexavalent group; Fig. 5—Primary anaphase side view; Fig. 6—Secondary anaphase side view.

equatorial plane. Metaphase and early anaphase side views show that the bivalents consist of two parallel rod-shaped chromosomes, without any structural connection along their entire length. In the most favorable cases, one can see that the corresponding ends of the paired chromosomes are turned a little apart. There is, therefore, no sign of chiasmata. From pachytene to metaphase, passing through stages like that represented in Fig. 4, one can follow the progressive shortening of the bivalents, without discovering any peculiar aspect that might suggest the existence of chiasmata.

A very remarkable peculiarity of *Rhopalurus*' meiosis is that in very early anaphase, when the chromosomes are still close to the equator, they already show clear symptoms of telophase disorganization. At that time, they appear much thinner and less compact than at metaphase and are enveloped by a sort of rarefied cloud that makes their boundaries much less distinct than previously. However, in individual chromosomes suitably orientated, it can be seen that they are more or less strongly bent toward the poles (Fig. 5). Later, the chromosomes become



more and more indistinct and the cloud denser, rendering further analysis of their behaviour impossible.

The hexavalent group, which can be recognized long before metaphase (Fig. 4), is orientated in such a way that two large and one small chromosomes move to each pole.

Secondary spermatocytes have 14 small chromosomes, 11 derived from the normal bivalents and three from the hexavalent complex (Fig. 3). Although very short, they are bent toward opposite poles as they start anaphase separation (Fig. 6).

#### Discussion

One of the best arguments favouring the terminal dicentricity of Scorpion chromosomes seems to be the remarkable ease with which they break into pieces and give rise to the most varied kinds of translocation figures.

It seems to me that chromosomes possessing a series of localized centromeres do not fail to orient correctly, and therefore do not break with such ease. Spontaneous translocation, when occurring in so high a frequency as in Scorpions, is certainly a valuable indication of a high rate of fragmentation. When the first individual of a population picked up by chance in nature shows translocations, we can conclude that chromosome fragmentation is a common affair and, consequently, that we are dealing with chromosomes bearing two centromeres that, if not at the ends, are at least situated far apart from one another.

*Rhopalurus rochai* is in that situation. The hexavalent complex, found in all primary spermatocyte metaphases, places this species in the same category as those of *Tityus* so far as the structure and behaviour of the chromosomes are concerned. Pairing is here, as in *Tityus*, side-by-side. As in *Tityus*, *Rhopalurus* pachytene chromosomes undergo a progressive and regular shortening process, and become thicker and thicker, without showing any structural aspect that could suggest the presence of chiasmata. To postulate that the chiasmata have terminalized before pachytene is incongruous. One must, therefore, assume that the paired chromosomes, parallel to but separate from one another, as they appear at metaphase and early anaphase, are, in fact, entirely free to move independently to opposite poles. The bending of the chromosomes while moving toward the poles is in full agreement with their assumed structure. It is clear that, if they were provided with diffuse or multiple centromeres, they should move with the convex side in advance. These, then, are the arguments for placing *Rhopalurus* with the Scorpions that have chromosomes with one centromere at each end.

#### Acknowledgment

The author is indebted to Dr. Stanley G. Smith (Forest Insect Laboratory, Sault Ste. Marie, Ont. Canada) for corrections in the manuscript and valuable suggestions.

#### Summary

*Rhopalurus rochai*, a Scorpion of the family Buthidae, parallels the species of *Tityus* in the structure and behaviour of its chromosomes. A diplotene phase is lacking in meiosis and the paired chromosomes are never connected by chiasmata. The rod-shaped primary metaphase chromosomes orientate themselves parallel to the equator. The partners separate parallel to one another. Telophase disorganization of the chromosomes begins early, when they are still close to the equator. At that time, they appear much thinner and less compact than previously and have their ends pointing to the pole towards which they are moving. These facts lead to the conclusion that *Rhopalurus* chromosomes are provided with two centromeres, one at each end.

The single male studied has spermatogonia with 28 short chromosomes, primary spermatocytes with 11 thick rod-shaped chromosomes and a translocation group formed by 6 elements, and secondary spermatocytes with 14 chromosomes, 11 derived from the normal bivalents and 3 from the hexavalent complex.

### References

- (1) Brieger, F. G. and E. A. Graner. 1943. On the cytology of *Tityus bahiensis* with special reference to meiotic prophase. *Genetics*, 28: 269-274.
- (2) Piza, S. de Toledo, Jr. 1939. Comportamento dos cromossomos na primeira divisao do espermatocito do *Tityus bahiensis*. *Sci. Genet.*, 1: 255-261.
- (3) Piza, S. de Toledo, Jr. 1940. Poliploidia natural em *Tityus bahiensis* (Scorpiones) associada a aberracoes cromossomicas espontaneas. *Rev. Biol. Hyg.*, 10: 143-155.
- (4) Piza, S. de Toledo, Jr. 1941. Chromosomes with two spindle attachments in the Brazilian scorpion *Tityus bahiensis* Perty. *J. Hered.*, 32: 423-426.
- (5) Piza, S. de Toledo, Jr. 1943. The uselessness of the spindle fibers for moving the chromosomes. *Am. Nat.*, 77: 442-462.
- (6) Piza, S. de Toledo, Jr. 1943. Meiosis in the male of the Brazilian scorpion *Tityus bahiensis*. *Rev. Agric.*, (Piracicaba,) 18: 249-276.
- (7) Piza, S. de Toledo, Jr. 1943. A proposito da meiose do *Tityus bahiensis*. *Rev. Agric.*, (Piracicaba), 18: 351-369.
- (8) Piza, S. de Toledo, Jr. 1947. Notas sobre cromossomos de alguns escorpioes brasileiros. *Ann. Esc. Sup. Agr. "Luiz de Queiroz"*, 4: 169-176.
- (9) Piza, S. de Toledo, Jr. 1947. Interessante comportamento dos cromossomos na espermatogênese do escorpio *Isometrus maculatus* De Geer. *Ann. Esc. Sup. Agr. "Luiz de Queiroz"*, 4: 177-182.
- (10) Piza, S. de Toledo, Jr. 1948. Primeiras observacoes sobre os cromossomos de *Tityus trivittatus* Krpl. (Scorpiones-Buthidae). *Rev. Agric.*, (Piracicaba), 23: 177-180.
- (11) Piza, S. de Toledo, Jr. 1949. "Ouro Preto", nova e interessante raca cromossomica de *Tityus bahiensis* (Scorpiones-Buthidae). *Sci. Genet.*, 3: 147-159.
- (12) Piza, S. de Toledo, Jr. 1950. The present status of the question of the kinetochore. *Gen. Iber.*, 2: 193-199.
- (13) Piza, S. de Toledo, Jr. 1952. Primeiras observacoes sobre os cromossomos do *Tityus metuendus* Pocock (Scorpiones-Buthidae). *Sci. Genet.*, 4: 162-167.
- (14) Rhoades, M. M. and W. E. Kerr. 1949. A note on centromere organization. *Proc. Nat. Acad. Sci.*, 35: 129-132.
- (15) Sharp, L. W. 1943. Fundamentals of Cytology. McGraw Hill Book Company, Inc., New York and London, First Edition, Fig. 80, p. 110.
- (16) Sharp, L. W. 1943. The same, second impression. Same p. and fig.
- (17) White, M. J. D. 1945. Animal Cytology & Evolution. Cambridge Univ. Press, VIII-375.

(Received September 12, 1957)

## Trinidad Encyrtidae II. Some Additional Mealybug Parasites

By FRED D. BENNETT

Commonwealth Institute of Biological Control

During the investigation of mealybug parasites in Trinidad seven species of *Aenasius*, one of them new, and a new species of *Zarhopalus* have been reared. The new species are described herein.

### Genus *Aenasius*

Compere, (Proc. Hawaii. ent. Soc., 9, pp. 383-404, 1937) gave a comprehensive review of the genus, described several new species and provided a key for the separation of the known species. Recently three additional species have been described, *Aenasius masii*, by Domenichini (Boll. Zool. agrar. bachic., 17, 157-180, 1951) from Peru, *Aenasius theobromae* by Kerrich (Bull. ent. Res., 44, 789-810, 1953) from Trinidad, and *Aenasius bolowi* by Mercet (Rev. Acad., Madrid, 41, 461-468, 1947) from Costa Rica.

Seven species of *Aenasius* have been reared from Trinidad in recent years. The author is indebted to Mr. H. Compere for assistance in identifying several of the species listed below.

#### 1. *Aenasius advena* Comp.

Compere (1937) described this species from Hawaii. Later an adult collected in Brazil was placed in this species by Compere (Univ. Calif. Publ. Ent., 7, 55-74, 1939). Kerrich (1953) consigned specimens received from Fiji to *advena*. Specimens have been reared in Trinidad from *Ferrisiana virgata* (Ckll.) on *Theobroma cacao*, *Cocos nucifera*, *Gliricidia sepium*, *Psidium guajava* and *Coccoloba uvifera*.

#### 2. *Aenasius frontalis* Comp.

Described by Compere from Panama. It has been reared in Trinidad from *Ferrisiana virgata* (Ckll.) on *Theobroma cacao* and *Cocos nucifera*.

#### 3. *Aenasius hyettus* Walker.

Compere lists the distribution as Grenada, B.W.I., St. Vincent, B.W.I. and Panama. This species is relatively common in Trinidad. It has been reared from *Ferrisiana virgata* (Ckll.) on *Theobroma cacao*, *Cocos nucifera*, *Gliricidia sepium*, *Psidium guajava*, *Coccoloba uvifera* and *Acalypha hispida*.

#### 4. *Aenasius theobromae* Kerrich.

Described by Kerrich (1953) from specimens reared from *Dysmicoccus brevipes* (Ckll.) on *Theobroma cacao* received from Professor Kirkpatrick, Trinidad. Specimens were reared from the same host in 1952, and 1953 by the author.

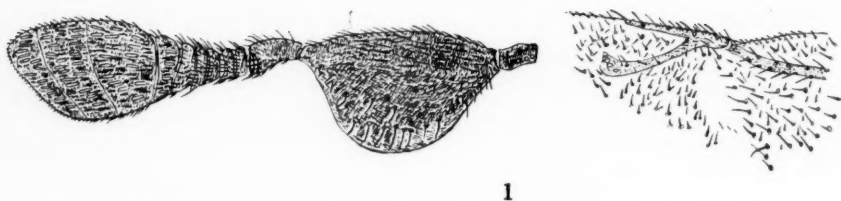
#### 5. *Aenasius cariocus* Comp.

Described from one female collected by H. Compere in Brazil. Specimens collected by D. Taylor in Colombia in 1953 were determined as *cariocus* by Mr. Compere. Specimens of this species have been reared from *Dysmicoccus brevipes* (Ckll.) on *Theobroma cacao*.

#### 6. *Aenasius phenacocci* new species.

This species runs to couplet 8 in Compere's key, (Proc. Haw. Ent. Soc. IX, pp. 388-391, 1937) and appears to be most closely related to *A. maplei* Comp. It may be separated from the species in couplet 8 by altering the couplet as follows:

- 8 Forewing with a small, hairless hyaline area distad to the termination of the post-marginal and stigmal veins ..... 8a  
Forewing without such a small hairless hyaline area. Trinidad ... *phenacocci* new species



1

Fig. 1. *Aenasius phenacocci* new species. Female: antenna and forewing venation.

- 8a Ocelli in an acute angle; frontovertex at the narrowest part about one-fifth as wide as the head. West Indies, Panama ..... 7. *hyettus* (Walker)  
 Ocelli in a right angle; frontovertex at the narrowest part slightly more than one-fourth as wide as the head. California ..... 8. *maplei* Comp.

### Female

Length 1.8 mm. Colour of frontovertex variable from brassy green to blue green; ocellar area not noticeably darker; facial impression slightly less green; area around mouth almost black. Pronotum, mesoscutum, axillae and scutellum dark with bluish or bluish-green slightly metallic reflection. Sides and under parts of thorax and abdomen black. Antennae black. Front and hind legs except for tarsi black; tarsi brownish to fuscous. Mid-femur brown apically, mid-tibia brownish-black, apical spur black, tarsi light brown to almost whitish. Forewings deeply embrowned, pale towards the apex.

Frontovertex at narrowest part slightly more than one-fourth the head width; ocellar triangle acute; two more or less distinct rows of coarse umbilicate punctuations in addition to the orbital rows of smaller punctuations descending between the anterior orbits and facial impression.

Mesoscutum, scutellum and axillae finely punctate, reticulate. Scutellum almost plane, at the base a short median impressed line. Axillar-scutellar sutures faint.

Scape widely expanded considerably less than twice as long as wide (40: 25); club about one and one-half times as long as wide and about as wide as scape.

Marginal vein short, not much more than twice as long as wide, plainly shorter than post-marginal vein; post-marginal vein not reaching as far distad as the stigmal vein, no hyaline hairless break just beyond the apex of post-marginal and stigmal veins.

### Male

Length 1.4 mm. Black, tarsi except for apical joints dirty white. Otherwise agrees with Compere's description of the male *Aenasius maplei*.

*Type locality*: I.C.T.A., Trinidad.

*Type*: U.S.N.M. No. 63501.

*Remarks*: Described from numerous females (holotype and paratypes) and a single male (allotype) reared from *Phenacoccus gossypii* Townsend and Cockrell collected on a wide range of host plants. The females vary considerably in size, ranging from 1.2 to 2.0 mm. in length.

Attempts to breed this species in the laboratory have not been entirely successful. Limited reproduction has occurred on several occasions but did not result in a marked increase in stocks. Males are seldom encountered and mating is not essential for the production of female progeny.

Several adults ranging from 1.2-1.6 mm. in length reared from *Phenacoccus* sp. nr. *parvus* Morr. were at first considered to represent another new species.

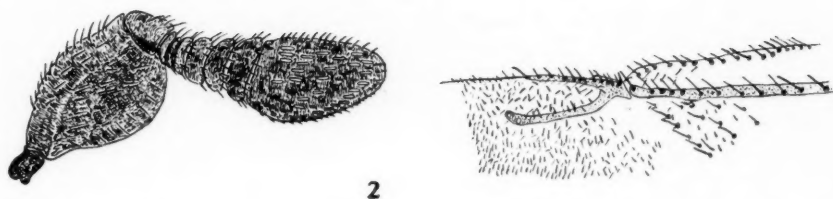


Fig. 2. *Zarhopalus putophilus* new species. Female: antenna and forewing venation.

However, as they appear identical in structure and colouration they have been referred to *A. phenacocci*.

#### 7. *Aenasius* sp.

Specimens reared from *Macrocephalicoccus loranthi* Morr. have been assigned to *Aenasius* and probably represent a new species. The condition of the specimens is too poor to warrant describing this species.

#### Genus *Zarhopalus*

Specimens of an Encyrtid reared from the mealybug *Puto barberi* (Ckll.) were determined by Mr. H. Compere as *Zarhopalus* new species. Mr. Compere kindly sent me a specimen of the closely related species *Zarhopalus corvinus* (Girault) for comparative purposes.

The genus *Zarhopalus* was revised by Timberlake (Univ. Calif. Publ. Ent., 3, pp. 235-236, 1924). In his key to the three species found in the United States the Trinidad specimens run closest to *corvinus* (Girault) but may be separated by the broader scape. In *corvinus* the scape is twice as long as broad but in *putophilus* new species only one and a half times as long as broad.

#### *Zarhopalus putophilus*, new species.

##### Female

Length 1.7 mm. Head, pronotum, mesonotum, scutellum and axillae, bright bluish green, the greenish colouration more pronounced than in *corvinus*. First abdominal tergite with a distinct greenish tinge. Side and ventral areas of thorax and abdomen black. Legs blackish or brownish-black; tarsi more or less fuscous with apical segment of each tarsus blackish; spur of middle tibia fuscous. Antennae black; eyes black, ocelli reddish.

Frontovertex almost twice as long as wide (25: 14); inner orbits of eyes nearly parallel. Frontovertex with sparsely scattered shallow pin-punctures, each puncture bearing a short colourless seta. Facial impression deep with steep sides almost carinated at junction with the frons; the antennal scrobes on an elevated area surrounded by a deep subcircular impression. Ocelli in a right-angled triangle.

Antennal scape broadly expanded ventrally about one and one-half times as long as broad; pedicel longer than the first three segments of funicle. Funicular segments all transverse, broader than long; club entire, slightly narrower than scape. Mandibles with three teeth, the centre tooth most prominent and longest.

Mesoscutum in addition to several setiferous punctures finely reticulate; scutellum smooth except for setiferous punctures, with a short median longitudinal depressed line at base. Axillar-scutellar sutures plainly visible; axillae narrowly separated. Setae on mesoscutum and scutellum black. Mesopleura

smooth and shiny. Abdomen shorter than thorax, about as broad at base as long. Ovipositor not exerted.

Forewings pale at base, strongly embrowned in stigmal area, fading somewhat towards the apex. Post-marginal vein almost as long as stigmal vein; marginal vein short, barely longer than wide.

*Male*: unknown.

*Type locality*: I.C.T.A., Trinidad, B.W.I.

*Type*: U.S.N.M. No. 63502.

*Remarks*: Described from numerous specimens including holotype and paratypes reared from *Puto barberi* on cocoa in 1952 and 1953. Additional specimens have been obtained from the same host collected on several other plants including *Lantana camara* L., *Acalypha wilkesiana* Muell., *Gliricidia sepium* (Jacq.) and *Coccolobis uvifera* L.

*Zarhopalus* is the only primary parasite that has been reared from *Puto barberi* in Trinidad. A few specimens of *Achrysopophagus dactylopii* (How.), which emerged from *Puto barberi* were undoubtedly hyperparasitic on *Zarhopalus*.

(Received May 1, 1957)

## Laboratory Studies on the Food of Some Coccinellids (Coleoptera) Found in Ontario Peach Orchards<sup>1</sup>

By WM. L. PUTMAN<sup>2</sup>

Entomology Laboratory, Vineland Station, Ontario

Food habits and occurrence of the commoner species of coccinellids in peach orchards of the Niagara Peninsula, Ontario, are being investigated in connection with a study of the effects of pesticides on biological control agencies. Results of a study of *Stethorus punctillum* Weise have already been published (Putman, 1955). The present account deals with laboratory tests of feeding, mostly during June and July from 1952 to 1955, with prey of special economic importance in peach orchards.

The species concerned are *Coleomegilla maculata lengi* Timb., *Hippodamia convergens* Guer., *H. tredecimpunctata tibialis* (Say), *H. parenthesis* (Say), *Adalia bipunctata* (L.), *Coccinella transversoguttata* Fald. (vars. *quinquenotata* Kby., *nugatoria* Muls., and intermediate forms), *C. trifasciata perplexa* Muls., *C. novemnotata* Hbst., *Cycloneda sanguinea* (L.), and *Anatis quindecimpunctata* (Oliv.). Subspecific names will not be used subsequently.

### General Methods

Field-collected adults were caged over aphid-infested chrysanthemums in the greenhouse or held individually in vials and supplied daily with aphids to obtain eggs from which the larvae and some of the adults used in the experiments were reared similarly. As the time and labour required to rear enough adults for all experiments proved prohibitive, field-collected adults were used in certain experiments as noted later. It was impossible to obtain adequate numbers of all species for some experiments because the species varied greatly in seasonal and yearly abundance and because some types of experimental prey were available only for a few days in the year.

<sup>1</sup>Contribution No. 3637, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Entomologist.



During the experiments the insects were kept individually in cotton-stoppered glass vials, either  $\frac{1}{2}$  by 3 or 1 by 6 inches, depending on the instar of the predator and the type of prey. The vials were held in covered glass vessels containing dishes of a saturated solution of sodium chloride, which maintained a relative humidity of approximately 76 per cent at 20°C. The vessels were kept on a shelf outside the laboratory but sheltered from the sun.

The aphids, unless otherwise specified, were *Rhopalosiphum rufomaculatum* (Wilson), reared on chrysanthemum in the greenhouse. During the heat of midsummer this species did not thrive and the supply was sometimes augmented by field collections of other species. The two-spotted spider mite, *Tetranychus telarius* (L.), was from a greenhouse culture reared on broad bean, *Vicia faba* L. The European red mite, *Metatetranychus ulmi* (Koch), was collected from peach and plum orchards where no persistent insecticides had been used. Eggs of the oriental fruit moth, *Grapholitha molesta* (Busck), were obtained by caging adults from a laboratory stock or from field-collected larvae in glass jars lined with waxed paper. Eggs of *Pulexinaria vitis* (L.) were obtained by collecting ovisacs from peach orchards.

In some experiments the frass of the beetles was examined by softening the pellets in a drop of dilute sodium hydroxide solution on a slide, dispersing them in a drop of Hoyer's medium and covering them with a cover glass. The number of prey eaten was determined under a microscope by counting the more heavily sclerotized and easily identified fragments, such as the tips of the rostrum and the tarsi of aphids.

#### Feeding on Aphids

All of the species concerned have long been known to feed upon aphids of many species, and a number of authors, notable Clausen (1916) and others listed by Balduf (1935) and Clausen (1940), have given data on the rate of prey consumption by certain species. During the present studies the adults of all the species oviposited for long periods and the larvae were reared with low mortality when they were fed aphids, but most of these were in mass cultures and precise records were not kept.

A small-scale test was carried out to determine the rate of aphid consumption by adults of two species to furnish a standard to which the consumption of other prey could be compared. Field-caught adults were confined in vials with an excess of aphids, which were replenished daily. Three to six days after they were put in the vials, the frass produced during a 24-hour period was examined for aphid remains. The number of aphids represented in the frass produced during this period was assumed to equal the number eaten during a similar length of time. The frass of 16 of *A. bipunctata* contained remains of 0 to 129 aphids each, with an average of 32.0; that of 17 of *C. transversoguttata*, a larger species, contained 0 to 79, with an average of 47.3. Two of *A. bipunctata* and one of *C. transversoguttata* had apparently not fed on aphids for at least 24 hours; the refusal of other normally acceptable prey by some individuals can therefore be expected.

#### Feeding on Oriental Fruit Moth

Reared or collected adults were confined for three days, or longer, with eggs of the oriental fruit moth that had been laid on waxed paper. About 10 eggs were usually put in a vial. Sixteen out of 19 of *C. maculata* fed readily on the eggs. Most of the beetles began eating them on their first contact and usually ate all available, up to 28, within 24 hours. All of 11 reared larvae in the last two (third and fourth) instars ate the eggs equally as freely.

Of 22 adults of *H. convergens*, one, after refusing the eggs the first day, accepted them readily for three days, eating up to 64 per day; another ate 4 within three days, and the others refused them. Of 12 larvae, 3 ate small numbers of eggs, up to 14, within three days.

None of 8 adults of *H. parenthesis* ate the eggs, but 2 of 9 larvae ate up to 4 within three days.

One of 9 adults of *H. tredecimpunctata* ate one egg within 3 days.

None of 5 adults of *C. sanguinea* accepted the eggs; one of 9 larvae ate 5 eggs within 3 days.

Four of 13 adults of *A. bipunctata* ate up to 6 eggs and 5 of 15 larvae ate up to 5 eggs within 3 days.

Of 5 adults of *C. transversoguttata*, 8 of *C. novemnotata*, and 7 of *C. trifasciata*, none accepted the eggs. One of 5 larvae of *C. transversogutta*, one of 4 of *C. novemnotata*, and 3 of 6 of *C. trifasciata* ate not more than 3 within 3 days.

All of the coccinellids accepted aphids offered at the end of the experiment, except a few larvae that were about to pupate.

As the experiment was set up each coccinellid was watched until it had made contact with the eggs. Except most individuals of *C. maculata* and one adult of *H. convergens*, they did not appear to recognize the eggs as prey. The egg of the oriental fruit moth is lenticular and closely appressed to the leaf, and does not offer any obstacle as the beetle walks over it. It is possible that in those cases where only some of the eggs were consumed they had first been detached or lacerated by the claws of the coccinellids, which were very active.

Some of the eggs hatched in vials containing some individuals of all the coccinellid species in the experiment. The young larvae were invariably eaten.

#### Feeding on the Two-Spotted Spider Mite

Larvae newly hatched from eggs laid in confinement were supplied with bean leaves heavily infested with the two-spotted spider mite. The initial number of larvae and the percentage that reached the adult stage for each species were as follows: *C. maculata*, 17 and 100; *H. convergens*, 23 and 61; *H. parenthesis*, 15 and 80; *H. tredecimpunctata*, 15 and 60; *A. bipunctata*, 16 and 31; *C. sanguinea*, 13 and 15; *C. transversoguttata*, 16 and 0; *C. novemnotata*, 16 and 0; *C. trifasciata*, 16 and 0; *A. quindecimpunctata*, 8 and 0.

Most larvae of the three species of *Coccinella* died in the first instar; a few that reached the early second instar may have fed previously on the eggs of their own species. The larvae of *A. quindecimpunctata* died in the first to third instars. In the other species in which less than 100 per cent of the larvae reached maturity, mortality occurred throughout the larval and pupal periods. For example, in a series of 10 larvae of *A. bipunctata*, 1 died in the first instar, 3 in the second, 3 in the third, and 2 in the fourth, only one reaching maturity. Some of the adults in these species were also somewhat dwarfed.

Series of three species, *C. maculata*, *H. convergens*, and *A. bipunctata*, which had different levels of survival in the foregoing tests, were reared on the mite in comparison with parallel series reared on aphids to determine the relative effects of these foods on the duration of the larval period. The results (Table I) showed that larvae of *H. convergens* and *A. bipunctata* required nearly twice the time for development when fed mites as when fed aphids. The prolongation extended through all instars; for example, the mean durations of successive instars of *H. convergens* when fed aphids were 3, 3, 2, and 4 days, and when fed mites, 5.1, 3.1, 3.5, and 10.2 days. The difference in mean duration of the larval period of *C. maculata* was slight, although it was highly significant by Student's *t* test.

TABLE I  
Durations of Larval Periods of Coccinellids Fed on Aphids and on Two-Spotted Spider Mite

Species	Food	Original Number of larvae	Number matured	Larval period, days	
				Range	Mean
<i>Coleomegilla maculata</i>	Aphids	10	10	11-12	11.7
	Mites	9	9	12-14	12.9
<i>Hippodamia convergens</i>	Aphids	8	8	12	12
	Mites	8	4	20-23	21.8
<i>Adalia bipunctata</i>	Aphids	10	9	14-15	14.3
	Mites	10	1	26	26

This slight difference was possibly due to lack in quantity of food rather than quality, for the older larvae that were given mites spent much more time in searching for this small prey than did those given aphids.

To determine the longevity of adults when fed on the two-spotted spider mite, series of newly transformed adults maturing in June and July were supplied with the mite for a maximum of 50 days. The larvae had been reared on aphids, except some of *C. maculata* that had been reared on the mite. The results (Table II) show that *C. maculata* survived much better than the other species. Directly comparable series fed on aphids were not available, but other work had shown that most adults of all the species lived longer than 50 days and often till at least the end of the season when fed aphids. As there was no consistent difference in longevity between the sexes the latter are not differentiated in the table. The great variation in longevity among individuals of some species, particularly

TABLE II  
Longevities of Adult Coccinellids Fed on the Two-Spotted Spider Mite

Species	Original Number	Number living at		
		10 days	20 days	50 days
<i>Coleomegilla maculata</i> . . . . .	13	11	11	8
<i>Hippodamia convergens</i> . . . . .	12	11	4	2
<i>H. tredecimpunctata</i> . . . . .	4	4	2	1
<i>Adalia bipunctata</i> . . . . .	6	2	2	0
<i>Cycloneda sanguinea</i> . . . . .	10	2	0	0
<i>Coccinella transversoguttata</i> . . . . .	6	3	0	0
<i>C. novemnotata</i> . . . . .	3	2	0	0
<i>C. trifasciata</i> . . . . .	6	4	1	0

*H. convergens*, may have been due to some being in diapause. Most of large numbers of field-caught adults of most of the species died within four to six days when confined without food, but some of those caught in July and August and presumably in diapause lived up to 12 days. Diapause adults of *Stethorus punctillum* are also known to require less food than reproducing ones (Putman, 1955).

Except *C. maculata*, the adults in this experiment, as well as in others, fed upon the mites in a desultory manner very different from the way they attacked aphids. Some individuals, particularly of *Coccinella* spp., were never seen to attack the mites. It was obvious both from the observed rate of feeding and from the amount of frass produced that individuals feeding on mites ate a considerably smaller bulk of food than those feeding on aphids, again with the exception of *C. maculata*.

The next experiment confirmed the relatively short life of adults of most of the species when feeding on the two-spotted spider mite. None of the females in the foregoing experiment produced eggs, which was not conclusive because they had not been fertilized. Another experiment was therefore set up to test the effect of the mite as prey on egg production. Females reared on aphids or emerging from field-collected pupae were confined with males and fed aphids until they began to oviposit, when they were placed separately with two-spotted spider mites. All of 6 of *C. maculata* continued to oviposit until they were discarded after 24 to 60 days. Among 5 of *H. convergens*, 11 of *A. bimaculata*, 14 of *C. transversoguttata*, and 7 of *C. trifasciata*, none oviposited for more than 6 days; most died within 5 to 10 days and all within 17 days. *H. tredecimpunctata* behaved differently; all of 9 females ceased oviposition within two days after being given mites, but 5 were still living after 20 days. They were then given aphids, whereupon they resumed oviposition within 4 to 7 days. The lengths of the oviposition periods of the various species when feeding on aphids were not determined, but in routine rearing numbers of all the species were still ovipositing after one to two months.

Those coccinellids that fed upon the mite consumed all stages together with the webbing.

#### Feeding on the European Red Mite

Infestations of the European red mite dense enough to bring the larvae of the coccinellids to maturity or to support the adults for an appreciable length of time could not be found on foliage free of toxic spray residues. Enough mites were available to feed 10 newly hatched larvae of each of three species for 6 days; within that time all of *C. maculata* reached the third instar, a rate of development comparable to that of larvae fed aphids or two-spotted spider mites. Five of *H. convergens* reached the second instar and the others were more or less moribund, and all of *A. bipunctata* died in the first or second instar.

Reared or field-caught adults of several species, unfed for 12 to 18 hours, were confined with peach leaves on which the numbers of the European red mite had been artificially increased by brushing onto them the mites from other leaves with a mite-brushing machine (Henderson and McBurnie, 1943). They were closely watched for four hours. Fifteen of 18 of *C. maculata*, 7 of 17 of *A. bipunctata*, 1 of 11 of *C. trifasciata*, and 1 of 14 of *H. tredecimpunctata* were observed eating the mites; only *C. maculata* ate them freely. Of 3 adults of *H. convergens*, 2 of *C. sanguinea*, 18 of *C. transversoguttata*, and 14 of *C. novemnotata*, none ate any mites. At the conclusion of the experiment those adults that had refused mites were offered rose aphids, *Macrosiphum rosae* (L.), which were invariably attacked within a few minutes.

TABLE III  
Numbers of Crawlers of *Pulvinaria vitis* Eaten in 24 Hours by Adult Coccinellids

Species	Number of beetles	Number eating crawlers	Number crawlers eaten	
			Maximum	Average
<i>Coleomegilla maculata</i> .....	11	9	123	24
<i>Hippodamia parenthesis</i> .....	3	3	5	4
<i>Adalia bipunctata</i> .....	15	8	26	4
<i>Coccinella transversoguttata</i> .....	10	3	13	7
<i>C. trifasciata</i> .....	10	6	36	11
<i>C. novemnotata</i> .....	5	2	5	1

#### Feeding on *Pulvinaria vitis* (L.)

Twelve adults and 6 larvae of *C. maculata*, 12 adults and 10 larvae of *A. bipunctata*, 7 adults of *C. transversoguttata*, and 12 adults of *C. trifasciata*, all unfed for three to four hours, were confined with intact ovisacs of *P. vitis* for 12 to 14 hours. None of the ovisacs were disturbed.

In a subsequent test the ovisacs were pulled apart to expose the eggs. Adult coccinellids were confined with the eggs for 16 to 18 hours and then held separately for two days, when the accumulated frass was examined. Seven of 10 of *C. maculata* and 3 of 11 of *A. bipunctata* ate 2 to 15 eggs each. None of 5 of *C. transversoguttata* ate any. Those observed eating or investigating the eggs were greatly hindered by the cotton of the ovisacs and the powdery substance mixed with the eggs and spent much time in cleaning their mouth parts.

Ten third- and fourth-instar larvae of *C. maculata*, 8 of *H. convergens*, 12 of *A. bipunctata*, and 7 of *C. trifasciata* were confined with eggs of *P. vitis* that had been shaken free from the ovisacs. Although a number of larvae were seen feeding on the eggs in a desultory manner, all were dead within seven days except one of *A. bipunctata*, which was near pupation at the beginning of the experiment and eventually produced an undersized adult. Before the larvae died some of the eggs had hatched, so that both eggs and crawlers were available as prey.

Adult beetles starved for 24 hours after feeding on aphids were confined for 24 hours with ovisacs from which newly hatched crawlers were emerging in large numbers. They were then held without food for three days and the accumulated frass was examined. Although crawlers were eaten by at least some individuals of all the species (Table III), the rate of consumption in terms of bulk, when the very small size of the crawlers is considered, was very much less than that of aphids as previously given.

Five adults of *C. maculata*, 5 of *H. convergens*, 8 of *H. tredecimpunctata*, 4 of *A. bipunctata*, 7 of *C. transversoguttata*, and 6 of *C. sanguinea* were confined for 24 hours with pieces of peach leaf bearing 4 or more scales of *P. vitis* in August, when the scales had nearly or quite reached maximum size for the season. Single scales were eaten by one adult of *C. maculata* and one of *C. transverso-*

*guttata*. As long as the scales remained in their usual position, closely appressed to the leaf, the beetles walked over them without any reaction. At least one of the scales eaten was crawling about the vial.

### Behaviour on Encountering Prey

Fleschner (1950) and other authors have described the behaviour of several predators in the presence of their prey, involving a thorough search of the immediate vicinity of the first encounter. Such behaviour was shown strongly toward aphids by all the coccinellid species in the present study. If a beetle was following a fairly straight course when it met an aphid, it devoured it and then progressed more hesitantly and frequently turned from side to side as it explored the substratum with antennae and palpi. Not only living aphids but also their exuviae or honey dew often evoked this reaction. Encounter with less attractive prey usually did not induce searching behaviour; if an individual of most of the coccinellid species met a mite or a scale crawler it might devour that particular prey but seldom or never followed with such behaviour. In keeping with its wider range of prey, *C. maculata* showed typical searching behaviour not only with aphids but also with the two-spotted spider mite, the European red mite, and eggs of the oriental fruit moth.

### Discussion

Although the interpretation of laboratory experiments on the selection of prey by predators is always doubtful, certain generalizations are evident. If a predator consistently refuses a particular species of prey in the laboratory or cannot develop normally on it, it can be safely concluded that it will be of no value in the natural control of that species in the field. If most individuals of a species eat only small numbers of the prey or if only occasional individuals eat it, the predator is also unlikely to be of importance. On the other hand, if a predator accepts the prey freely and especially if it develops normally when feeding exclusively upon it, the species is potentially important. Only species in this category are likely to exhibit the density-dependence characteristic of the most effective predators. Laboratory study thus serves to eliminate the unimportant species, so that only those likely to be influential need be given the field study needed to determine their true value.

By these criteria *C. maculata* is a potentially valuable predator with a wide range of prey; it fed freely on the two-spotted spider mite, the European red mite, and eggs of the oriental fruit moth, and it also attacked crawlers of *Pulvinaria vitis* more readily than the other coccinellids. Although the larvae developed normally on the two-spotted spider mite, natural infestations of this mite are very seldom dense enough to supply the large volume of food required by the older larvae, and the European red mite probably never reaches such a density. All the other species, as far as they were investigated, were primarily aphidophagous and had a much narrower range of acceptable prey; they fed only to a limited extent or not at all on the prey mentioned. *Coccinella* spp. had the most restricted range as the larvae of all three species did not develop on the two-spotted spider mite. None of the species tested ate the eggs or older nymphs of *Pulvinaria vitis* in any numbers. All fed readily on newly hatched larvae of the oriental fruit moth but on the trees these larvae are exposed for only a short time.

Because of its scarcity, little was learned about the food preferences of *A. quindecimpunctata*; also, *C. sanguinea* and some species of *Hippodamia* and *Coccinella* could not be included in all experiments. As the food habits of all species within each genus were very similar as far as they were investigated,



results for the species of *Coccinella* and *Hippodamia* more intensively studied may probably be true of the other local species of the same genera.

The range of prey of the larvae was in general similar to that of adults of the same species.

Some extension of the results to other prey not included in the investigations may be justified. The eggs of many Lepidoptera such as the codling moth, *Carpocapsa pomonella* (L.), and other olethreutids that are very similar to those of the oriental fruit moth should be assumed to be free from predation by most coccinellids until they are proved otherwise.

The avidity with which the prey was attacked, and whether it evoked searching behaviour, proved to be a good guide to its suitability, if allowance was made for the refusal of occasional individuals of the predator to attack any prey even after several hours without food. Although some species of prey not immediately attacked were eaten after several hours of confinement with the beetles, the numbers destroyed in such cases were always relatively small. It is true that many predators, including coccinellids, must spend part of their lives under semistarvation and therefore may accept relatively unattractive prey in the field, but coccinellids fly readily and are likely to leave environments where their preferred prey is scarce.

#### Summary

*Coleomegilla maculata lengi* Timb. fed readily on the two-spotted spider mite and the larvae developed normally on the same prey; this species also readily attacked the European red mite and eggs of the oriental fruit moth, and to a less extent the crawlers of *Pulvinaria vitis* (L.). *Hippodamia convergens* Guer., *H. tredecimpunctata tibialis* (Say), *Adalia bipunctata* (L.), *Coccinella transversoguttata* Fald., *C. trifasciata perplexa* Muls., and *Cycloneda sanguinea* (L.), in so far as they were tested, either refused the same species of prey or ate only small numbers after being deprived of food. Larvae of these species and of *Anatis quindecimpunctata* (Oliv.) could not develop normally on the two-spotted spider mite. Food preferences of the larvae were generally similar to those of adults of the same species. All the species mentioned are primarily aphidophagous except *C. maculata*, which is more or less polyphagous.

#### References

- Baludf, W. V. 1935. The bionomics of entomophagous Coleoptera. John S. Swift Co., St. Louis, Mo.
- Clausen, C. P. 1916. Life-history and feeding records of a series of California Coccinellidae. *Univ. California Pub. Ent. Tech. Bull.* 1: 251-299.
- Clausen, C. P. 1940. Entomophagous insects. McGraw-Hill Book Company, Inc., New York.
- Fleschner, C. A. 1950. Studies on searching capacity of the larvae of three predators of the citrus red mite. *Hilgardia* 20: 233-265.
- Henderson, C. F., and H. V. McBurnie. 1943. Sampling techniques for determining populations of the citrus red mite and its predators. *U.S. Dept. Agr. Circ.* 671.
- Putman, W. L. 1955. Bionomics of *Stethorus punctillum* Weise (Coleoptera: Coccinellidae) in Ontario. *Canadian Ent.* 87: 9-33.

(Received August 30, 1957)

### Book Notice

**THE BUTTERFLIES OF THE MALAY PENINSULA.** By A. Stephen Corbet, British Museum (Natural History), and H. M. Pendlebury, Director of Museums, F.M.S., and edited by N. D. Riley, Keeper of Entomology, British Museum (Natural History), vii+ 537 pp., 159 text figs., 55 pls. (8 in color). Oliver and Boyd, Edinburgh and London. Second Edition. 1956. Price £5, 5s.

The first edition of this book was published in Kuala Lumpur, Federated Malay States, in 1934. Since that time these two authors have made extensive and exhaustive studies of Malayan butterflies in existing collections and in the field. The second edition is a thoroughly comprehensive treatise on the rich butterfly fauna of the region.

The book is divided into three parts. Part one, the introductory part, deals in a general and concise manner with butterfly classification and distinguishing characters; methods of rearing; geographical distribution, with particular reference to the Malaysian subregion; migration; wing pattern differences, including pigments, polymorphism, geographical variation, mendelism, and mimicry; effect of Pleistocene glaciation on speciation in the region; mathematical considerations, including the application of the Fisher series and the index of diversity; a historical account of butterfly collecting in the Malay Peninsula; collecting methods; and the preparation and preservation of specimens.

Part two, the systematic section, comprises the major portion of the text. It deals with distinguishing characters for recognition, and with distribution and life histories, if known, of the 898 species occurring in the region. Keys are given for the separation of the various families, genera and species. The systematic arrangement, in general, follows that used in Seitz's *Macrolepidoptera of the World*.

Part three deals mainly with the nomenclatorial aspects. It contains a synonymic list of the 898 species and 89 subspecies occurring in the region; a list of known food plants of the butterfly families and subfamilies; a bibliography; and a short appendix. The general index is followed by one to scientific names, and by one to common names.

The 55 plates include 20 of genitalic illustrations, 27 of black and white, and 8 of colored photographs of the butterflies.

It is most regrettable that both of these authors did not live to see the publication, in book form, of results of over 20 years of exhaustive study. Their book will undoubtedly, for many years remain a classic, and a standard text and reference to the butterflies of the Malay Peninsula.

T. N. FREEMAN

## A Dispersal of Larvae of the Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae)<sup>1</sup>

By L. M. CASS<sup>2</sup>

Crop Insect Section, Entomology Laboratory  
Ottawa, Canada

In July, 1952, during studies on the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), at Merivale, Ontario, a large-scale dispersal of the larvae was observed. A field of early potatoes consisting of seven 100-foot rows, which was to be used as a source of supply of the insect for plant resistance studies, had been artificially infested on June 30 by placing an overwintered adult on each plant. The beetles laid eggs in large numbers and by the second week of July the plants were overpopulated with larvae. By July 14 the plants were stripped of foliage and the larvae were forced to feed on the stalks. On the morning of July 16 the starving larvae began to leave the plants in large numbers. Almost all left on the one day, some of them travelling considerable distances.

TABLE I

Numbers of larvae of the Colorado potato beetle of various instars found per 200 square feet<sup>1</sup> at various distances from two sides of the potato field from which they had dispersed, Merivale, Ontario, July 16, 1952

Distance from field, feet	Second instar	Third instar	Fourth instar	Total	Percentage of total recorded
5	21	51	142	214	30
10	9	51	148	208	29
20	6	32	85	123	17
30	1	8	49	58	8
50	6	9	45	60	8
75	0	6	32	38	5
100	0	2	8	10	1
200	0	0	2	2	0.3
250	0	0	1	1	0.2
Total	43	159	512	714	100.0

<sup>1</sup>Larvae counted on the day of dispersal in an area of 1 foot by 100 feet, paralleling the plant rows, on each side of the field.

Table I shows that the distance the larvae travelled depended on their stage of development. Fourth-instar larvae crawled 19 inches per minute on smooth, hard-packed soil, a roadway, and about nine inches per minute over rough, loose sandy loam. Some of the larvae penetrated 20 to 25 feet into a nearby field of timothy hay.

Gibson *et al.* (1925) stated that when the larvae leave the plants because of lack of food they move about aimlessly, but at Merivale 58 per cent of the larvae moved westwards towards a second potato field 350 feet distant. As there was a westerly wind, this movement may have been an olfactory response; however,

<sup>1</sup>Contribution No. 3631, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

<sup>2</sup>Technician

according to Chin (1952), the olfactory sense in the larva of *L. decemlineata* is short-ranged. A small percentage of the larvae at Merivale fed, but not extensively, on black bindweed, *Polygonum convolvulus* L.; lamb's quarters, *Chenopodium album* L.; and red-root pigweed, *Amaranthus retroflexus* L.

During the peak of the dispersal, 10 a.m.-8 p.m. on July 16, the air temperature averaged 74.2°F.

#### References

- Gibson, A., R. P. Gorham, H. F. Hudson, and J. A. Flock. 1925. The Colorado potato beetle in Canada. Can. Dept. Agr. Bull. 52 (n.s.) (Ent. Branch Bull. 27).  
Chin, C. T. 1950. Studies on the physiological relations between the larvae of *Leptinotarsa decemlineata* (Say) and some solanaceous plants. Veeman and Zonen, Wageningen, The Netherlands.

(Received August 7, 1957)

### Seventh Annual Meeting, Entomological Society of Canada

The seventh annual meeting of the Entomological Society of Canada was held jointly with the fifth annual meeting of the Entomological Society of Alberta at the Marquis Hotel, Lethbridge, from October 29 to 31. A total of 178 members and friends attended, including 14 from the United States and other countries and 10 wives. R. Glen, President, Entomological Society of Canada, presided. Addresses of welcome were given by C. W. Farstad, President, Entomological Society of Alberta; Mr. A. W. Shackleford, Mayor of the City of Lethbridge; Mr. H. Chester, Superintendent, Canada Experimental Farm, Lethbridge; and Dr. W. C. Broadfoot, Chief, Science Service Laboratory, Lethbridge. At the opening session, Dr. Glen gave a timely account of the complex relations of an entomological society to other scientific societies. Concerning co-ordinating bodies he discussed especially the roles of the International Council of Scientific Unions, the American Institute of Biological Sciences, and the Canadian Federation of Biological Societies, the last of which had been formed at Ottawa on October 11, 1957, with four member societies.

Invitation papers were presented at one session by three prominent entomologists, and symposia on resistance of plants to insects and on systemic insecticides for livestock at two sessions. Papers of which titles had been submitted were presented at two sessions of three sections each.

At a luncheon provided by courtesy of Canadian Sugar Factories Limited at the Marquis Hotel on October 29, L. A. Jacobson, Chairman of the Local Committee, presided. Mr. Frank Taylor, president of the host company, expressed the thanks of his industry for the services provided by the Science Service Laboratory at Lethbridge, particularly those by the entomologists. He also showed an interesting film on growing sugar beets in Alberta and the refinement of sugar from them.

At a banquet at the Marquis Hotel on October 30, provided by courtesy of the Province of Alberta, R. Glen was Chairman, and Hon. L. C. Halmrast, Minister of Agriculture for Alberta, Mayor A. W. and Mrs. Shackleford, and Dr. C. H. Hoffman, Assistant Director, Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md., were honoured guests. Hon. Mr. Halmrast welcomed the Entomological Society of Canada to its meeting in Alberta, extended greetings from the Alberta Depart-

ment of Agriculture, and paid tribute to the accomplishments of entomologists in Alberta. George Brown, Jr., delighted all with vocal solos: "All Day on the Prairie", "The Blue-Tailed Fly", and "Lucky Old Sun". The guest speaker of the evening, Mr. A. J. Cullen, was introduced by C. W. Farstad and gave, under the title "Trail Blazers", a scintillating account of the exploration and early settlement of Alberta; the thanks of the meeting were extended to Mr. Cullen by W. N. Keenan. A total of 213 members and friends attended.

The ladies were entertained at a theater party, at a cattalo barbecue at the home of Mrs. L. A. Jacobson, at a coffee party at the home of Mrs. C. W. Farstad, and on a conducted tour of the Taber sugar factory.

At the business session, R. Glen reported that a favourable financial position had been maintained by the Tenth International Congress of Entomology. The balance was expected, along with the revenue from sales of the *Proceedings*, to be adequate to finance the publication. However, final arrangements for the printing had not been made.

The report of the Editor, W. R. Thompson, showed that five additional supplements were on hand, three being in the hands of the printer; there were 70 papers on hand, enough for 12 regular issues of 48 pages each. On motion of D. G. Peterson and H. L. House, it was agreed that the Directors consider establishing an editorial board for *The Canadian Entomologist*. It was agreed that the size of the journal be increased by 16 pages per month.

The Treasurer, B. M. McGugan, provided copies of the audited financial statement for 1956, showing a surplus of \$1,504.96 for the period, and also an interim statement for January 1 to October 1, 1957, showing an estimated surplus of \$329.09. The mailing list was made up as follows: regular members, 566; honorary and life members, 12; subscribers, 399; exchanges, 99; advertisers, 6; total, 1,082.

There was much discussion on a recommendation of the Directors that, to finance the increase in size of the journal, the annual membership fees and subscription rates be increased by \$2 each, effective as of January 1, 1958. It was decided that the membership fee be \$6 for persons joining through a regional society and \$8 for those joining directly and that the subscription rate be \$10.

The Secretary stated that the ballot for the election of officers for 1957-59 was mailed to members in good standing (470) on June 14. A total of 232 ballots were cast, the following being elected: President-elect, 1957-58: M. L. Prebble; directors at large, 1957-59: W. J. Brown, J. Marshall, F. O. Morrison; directors representing regional entomological societies, 1957-59: G. R. Hopping, J. B. Maltais, R. M. Prentice. The following honorary members were elected on the mail ballot: G. J. Spencer and E. M. Walker. By the mail ballot the members also approved that the Board of Directors be empowered to elect an executive committee comprised of the President and two voting directors to carry out the executive functions of the Board. The preliminary announcement of the annual meeting was mailed on June 26. The program and the abstracts of papers were mailed on September 25.

A. V. Mitchener, Chairman of the Committee on Common Names of Insects, reported that 13 new common names were proposed and that five were approved and submitted to the chairman of the committee of the Entomological Society of America. The Committee recommended that it be made a standing committee of the Entomological Society of Canada; that the chairmen of the committees of the seven regional societies be members of the Committee, the

President-elect naming the chairman, one systematist from the Entomology Division, and another member at large if necessary to bring the total to nine; that the objects of the Committee be clearly defined; that the Committee recognize the common names as adopted by the Entomological Society of America; and that the Entomological Society of Canada suggest that the Entomological Society of America have two members from Canada on its committee on common names of insects, one being named by the Canadian committee. These recommendations were based on proposals of the Acadian Entomological Society. The report was adopted, the Directors to take further action if necessary.

W. A. Reeks, Convener of the Membership Committee, recommended that the incoming board consider whether the Membership Committee should consist of the secretaries of the national and regional societies.

Ten persons having been nominated for the seven vacancies in honorary memberships, R. Glen had asked that the nominations be submitted to the Directors by mail ballot, requesting that each director vote for no more than seven persons so that the number approved would probably not be greater than the number permitted by the constitution. As a result, two were elected. The Board had agreed that the eight persons who had not received the required number of votes might be renominated, the qualifications being desired in greater detail. There was considerable discussion concerning whether the procedure for electing honorary members might be improved.

The President of the Entomological Society of America had suggested that a branch or branches of the Entomological Society of America be formed in Canada. It was understood that the members of the American society in Canada should deal directly with that society in the matter.

W. G. Matthewman and W. A. Fowler were elected as auditors for the 1957 accounts.

A suggestion by D. B. Waddell that the Society consider improving the facilities for presenting papers at annual meetings by providing a chest microphone and a screen of the proper size for the meeting room and by having the seats arranged according to the type of screen was referred to the Directors.

On motion of A. D. Pickett and J. B. Adams, it was agreed that the Directors consider the desirability of affiliation of the Entomological Society of Canada with the Canadian Federation of Biological Societies and report at the annual meeting in 1958.

On behalf of G. P. Holland, who was absent from Canada, M. L. Prebble, President-elect, announced the personnel of the standing committees for 1957-58, as follows: Nominating Committee: J. G. Rempel (convener), H. L. House, R. R. Lejeune; Election Committee: J. W. Arnold (convener), W. G. Friend, J. R. Sharp; Membership Committee: E. J. LeRoux (convener), J. L. Auclair, R. O. Paradis.

The annual meeting in 1958 will be held jointly with the Entomological Society of Ontario at Guelph from October 29 to 31; that in 1959, with the Entomological Society of America at Detroit.

R. H. Wigmore, *Secretary*



MAR 29 1997

461  
21

▲